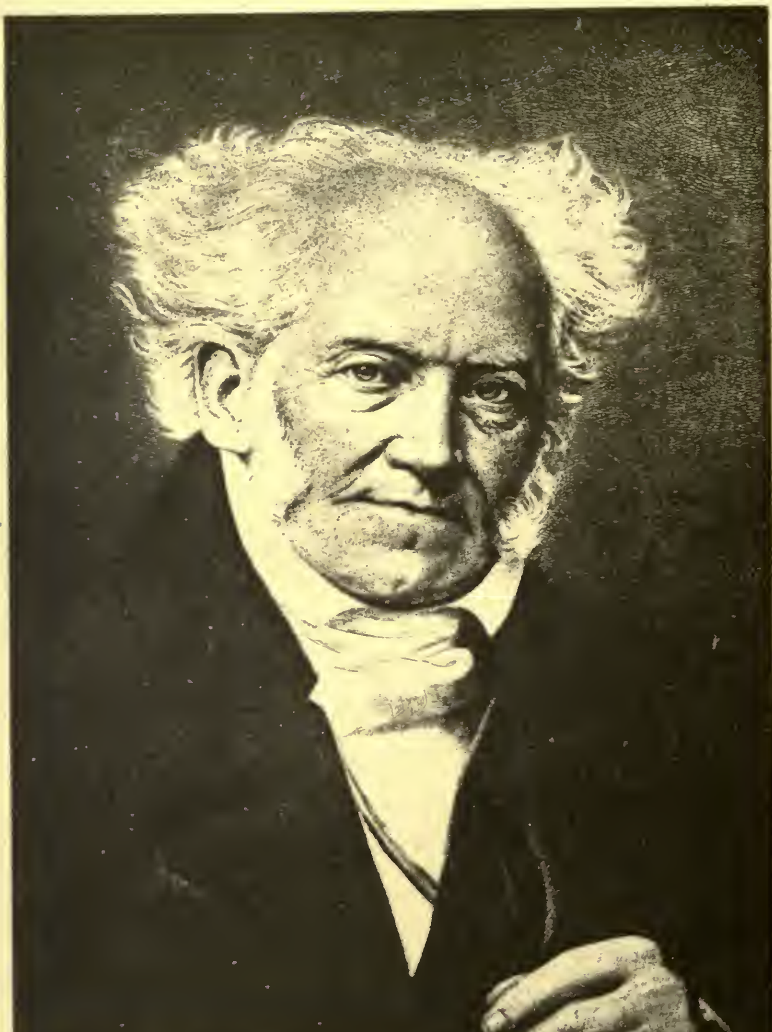

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MILLAR PUBLISHING COMPANY

225 Fifth Avenue, New York

San Francisco, Cal.
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Beacon Lights of Science

LESSONS IN ELECTRICITY

TO WHICH IS ADDED

AN ELEMENTARY LECTURE ON MAGNETISM

BY

JOHN TYNDALL, D.C.L., LL.D., F.R.S.

PROFESSOR OF NATURAL PHILOSOPHY IN THE ROYAL INSTITUTION OF GREAT BRITAIN.

WITH SIXTY ILLUSTRATIONS

PREFACE.

More than fifty years ago the Board of Managers of the Royal Institution resolved to extend its usefulness, as a centre of scientific instruction, by giving, during the Christmas and Easter holidays of each year, two courses of Lectures suited to the intelligence of boys and girls.

On December 12th, 1825, a Committee appointed by the Managers reported "that they had consulted Mr. Faraday on the subject of engaging him to take a part in the juvenile lectures proposed to be given during the Christmas and Easter recesses, and they found his occupations were such that it would be exceedingly inconvenient for him to engage in such lectures."

Faraday's holding aloof was, however, but temporary, for at Christmas, 1827, we find him giving a "Course of Six Elementary Lectures on Chemistry, adapted to a Juvenile Auditory."

The Easter lectures were soon abandoned, but from the date mentioned to the present time the Christmas lectures have been a marked feature of the Royal Institution.*

Last Christmas it fell to my lot to give one of these courses. I had heard doubts expressed as to the value of science-teaching in schools, and I had heard objections urged on the score of the expensiveness of apparatus. Both doubts and

* These brief historic references have already appeared in the preface to the "Forms of Water."

objections would, I considered, be most practically met by showing what could be done, in the way of discipline and instruction, by experimental lessons involving the use of apparatus so simple and inexpensive as to be within everybody's reach.

With some amplification, the substance of our Christmas Lessons is given in the present little volume.

LESSONS IN ELECTRICITY.

§ 1. *Introduction.*

Many centuries before Christ, it had been observed that yellow amber (*elektron*), when rubbed, possessed the power of attracting light bodies.

Thales, the founder of the Ionic philosophy (B.C. 580), imagined the amber to be endowed with a kind of life.

This is the germ out of which has grown the science of *electricity*, a name derived from the substance in which this power of attraction was first observed.

It will be my aim, during six hours of these Christmas holidays, to make you, to some extent, acquainted with the history, facts, and principles of this science, and to teach you how to work at it.

The science has two great divisions: the one called "Frictional Electricity," the other "Voltaic Electricity." For the present, our studies will be confined to the first, or older portion of the science, which is called "Frictional Electricity," because in it the electrical power is obtained from the rubbing of bodies together.

§ 2. *Historic Notes.*

The attraction of light bodies by rubbed amber was the sum of the world's knowledge of electricity for more than 2000 years. In 1600 Dr. Gilbert, physician to Queen Elizabeth, whose attention had been previously directed with great success to magnetism, vastly expanded the domain of electricity. He showed that not only amber, but various spars, gems, fossils, stones, glasses, and resins, exhibited, when rubbed, the same power as amber.

Robert Boyle (1675) proved that a suspended piece of rubbed amber, which attracted other bodies to itself, was in turn attracted by a body brought near it. He also observed the *light* of electricity, a diamond, with which he experimented, being found to emit light when rubbed in the dark.

Boyle imagined that the electrified body threw out an invisible, glutinous substance, which laid hold of light bodies, and, returning to the source from which it emanated, carried them along with it.

Otto von Guericke, Burgomaster of Magdeburg, contemporary of Boyle, and inventor of the air-pump, intensified the electric power previously obtained. He devised what may be called the first electrical machine, which was a ball of sulphur, about the size of a child's head. Turned by a handle, and rubbed by the dry hand, the sulphur sphere emitted light in the dark.

Von Guericke also noticed, and this is important, that a feather, having been first attracted to his sulphur globe, was afterward repelled, and kept at a distance from it, until, having touched another body, it was again attracted. He heard the hissing of the "electric fire," and also observed that an unelectrified body, when brought near his excited sphere, became electrical and capable of being attracted.

The members of the Academy del Cimento examined various substances electrically. They proved smoke to be attracted, but not flame, which, they found, deprived an electrified body of its power.

They also proved liquids to be sensible to the electric attraction, showing that when rubbed amber was held over the surface of a liquid, a little eminence was formed, from which the liquid was finally discharged against the amber.

Sir Isaac Newton, by rubbing a flat glass, caused light bodies to jump between it and a table. He also noticed the influence of the rubber in electric excitation. His gown, for example, was found to be much more effective than a napkin.

Newton imagined that the excited body emitted an elastic fluid which penetrated glass.

In the efforts of Thales, Boyle, and Newton to form a mental picture of electricity we have an illustration of the ten-

dency of the human mind, not to rest satisfied with the facts of observation, but to pass beyond the facts to their invisible causes.

Dr. Wall (1708) experimented with large, elongated pieces of amber. He found wool to be the best rubber of amber. "A prodigious number of little cracklings" was produced by the friction, every one of them being accompanied by a flash of light. "This light and crackling," says Dr. Wall, "seem in some degree to represent thunder and lightning." This is the first published allusion to thunder and lightning in connection with electricity.

Stephen Gray (1729) also observed the electric brush, snappings, and sparks. He made the prophetic remark that "though these effects are at present only minute, it is probable that in time there may be found out a way to collect a greater quantity of the electric fire, and, consequently, to increase the force of that power which by several of those experiments, if we are permitted to compare great things with small, seems to be of the same nature with that of thunder and lightning." This, you will observe, is far more definite than the remark of Dr. Wall.

§ 3. *The Art of Experiment.*

We have thus broken ground with a few historic notes, intended to show the gradual growth of electrical science. Our next step must be to get some knowledge of the facts referred to, and to learn how they may be produced and extended. The art of producing and extending such facts, and of inquiring into them by proper instruments, is the *art of experiment.* It is an art of extreme importance, for by its means we can, as it were, converse with Nature, asking her questions and receiving from her replies.

It was the neglect of experiment, and of the reasoning based upon it, which kept the knowledge of the ancient world confined to the single fact of attraction by amber for more than 2000 years.

Skill in the art of experimenting does not come of itself; it is only to be acquired by labor. When you first take a billiard cue in your hand, your strokes are awkward and ill-directed. When you learn to dance, your first movements are neither graceful nor pleasant. By *practice* alone, you learn to dance and to play. This also is the only way of learning the art of experiment. You must not, therefore, be daunted by your clumsiness at first; you must overcome it, and acquire skill in the art *by repetition.*

In this way you will come into direct contact with natural truth—you will think and reason not on what has been said to you in books, but on what has been said to you by Nature. Thought springing from this source has a vitality not derivable from mere book-knowledge.

§ 4. *Materials for Experiment.*

At this stage of our labors we are to provide ourselves with the following materials:

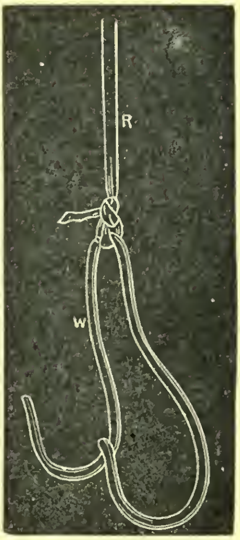


FIG. 1.

a. Some sticks of sealing-wax;

b. Two pieces of gutta-percha tubing, about 18 inches long and ¾ of an inch outside diameter;

c. Two or three glass tubes, about 18 inches long and ¾ of an inch wide, closed at one end, and not too thin, lest they should break in your hand and cut it;

d. Two or three pieces of clean flannel, capable of being folded into pads of two or three layers, about eight or ten inches square;

e. A couple of pads, composed of three or four layers of silk, about eight or ten inches square;

f. A board about 18 inches square, and a piece of india-rubber;

g. Some very narrow silk ribbon, R, and a wire loop, W, like that shown in fig. 1, in which sticks of sealing-wax, tubes of gutta-percha, rods of glass, or a walking-stick, may be suspended. I choose a narrow ribbon because it is convenient to have a suspending cord that will neither twist nor untwist of itself.

(I usually employ a loop with the two ends, which are here shown free, soldered together. The loop would thus be unbroken. But you may not be skilled in the art of soldering, and I therefore choose the free loop, which is very easily constructed. For the purpose of suspension an arrangement resembling a towel-horse, with a single horizontal rail, will be found convenient).

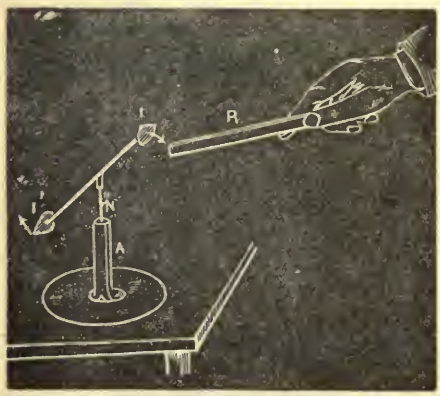


Fig. 2.

h. A straw, I I′, fig. 2, delicately supported on the point of a sewing needle N. This is inserted in a stick of sealing-wax A. attached below to a little circular plate of tin, the whole forming a stand. In fig. 3 the straw is shown on a larger scale, and separate from its needle. The short bit of straw in the middle, which serves as a cap, is stuck on by sealing-wax.

i. The name "amalgam" is given to a mixture of mercury with other metals. Experience has shown that the efficacy of a silk rubber is vastly increased when it is smeared over with an amalgam formed of 1 part by weight of tin, 2 of zinc, and 6 of mercury. A little lard is to be first smeared on the silk, and the amalgam is to be applied to the lard. The amalgam. if hard, must be pounded or bruised with a pestle or a hammer until it is soft. You can purchase sixpenny-worth of it at a philosophical instrument maker's. It is to be added to your materials.

k. I should like to make these pages suitable for boys without much pocket-money, and, therefore, aim at economy in my list of materials. But provide by all means, if you can, a fox's brush, such

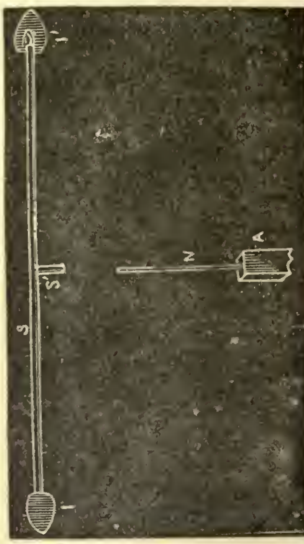


Fig. 3.

as those usually employed in dusting furniture.

§ 5. *Electric Attractions.*

Place your sealing-wax, gutta-percha tubing, and flannel and silk rubbers before a fire, to insure their dryness. Be specially careful to make your glass tubes and silk rubbers not only warm, but hot. Pass the dried flannel briskly once or twice over a stick of sealing-wax or over a gutta-percha tube. A very small amount of friction will excite the power of attracting the suspended straw as shown in fig. 2. Repeat the experiment several times and cause the straw to follow the attracting body round and round. Do the same with a glass tube rubbed with silk.

I lay particular stress on the heating of the glass tube, because glass has the

power, which it exercises, of condensing upon its surface into a liquid film, the aqueous vapor of the surrounding air. This film must be removed.

I would also insist on practice, in order to render you expert. You will therefore

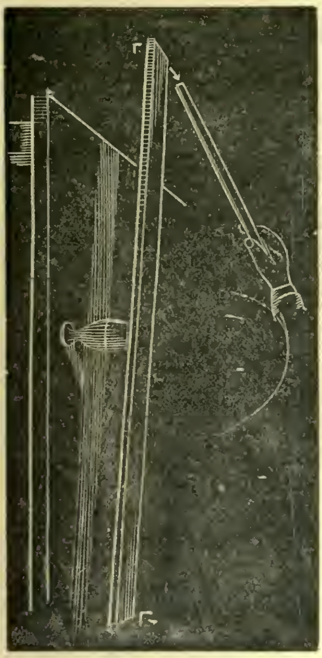


Fig. 4.

attract bran, scraps of paper, gold leaf, soap bubbles, and other light bodies by rubbed glass, sealing-wax, and gutta-percha. Faraday was fond of making empty egg shells, hoops of paper, and other light objects roll after his excited tubes.

It is only when the electric power is very weak, that you require your delicately suspended straw. With the sticks of wax, tubes, and rubbers here mentioned, even heavy bodies, when properly suspended, may be attracted. Place, for instance, a common walking-stick in the wire loop attached to the narrow ribbon, fig. 1, and let it swing horizontally. The glass, rubbed with its silk, or the sealing-wax, or gutta-percha, rubbed with its flannel, will pull the stick quite round.

Abandon the wire loop ; place an egg in an egg-cup, and balance a long lath upon the egg, as shown in fig. 4. The lath, though it may be almost a plank, will obediently follow the rubbed glass, gutta-percha, or sealing-wax.

Nothing can be simpler than this lath and egg arrangement, and hardly anything could be more impressive. The more you work with it, the better you will like it.

Pass an ebonite comb through the hair. In dry weather it produces a crackling noise ; but its action upon the lath may be made plain in any weather. It is rendered electrical by friction against the hair, and with it you can pull the lath quite round.

If you moisten the hair with oil, the comb will still be excited and exert attraction ; but if you moisten it with water, the excitement ceases ; a comb passed through wetted hair has no power over the lath. You will understand the meaning of this subsequently.

After its passage through dry or oiled hair, balance the comb itself upon the egg : it is attracted by the lath. You thus prove the attraction to be *mutual :* the comb attracts the lath, and the lath attracts the comb. Suspend your rubbed glass, rubbed gutta-percha, and rubbed sealing-wax in your wire loop. They are all just as much attracted by the lath as the lath was attracted by them. This is an extension of Boyle's experiment with the suspended amber (§ 2).

How it is that any unelectrified body attracts, and is attracted by the excited glass, sealing-wax, and gutta-percha, we shall learn by and by.

A very striking illustration of electric attraction may be obtained with the board and india-rubber mentioned in our list of materials (§ 4). Place the board before the fire and make it *hot* ; heat also a sheet of foolscap paper and place it on the board. There is no attraction between them. Pass the india-rubber briskly over the paper. It now clings firmly to the board. Tear it away, and hold it at arm's length, for it will move to your body if it can. Bring it near a door or wall, it will cling tenaciously to either. The electrified paper also powerfully attracts the balanced lath from a great distance.

The friction of the hand, of a cambric handkerchief, or of wash-leather fails to electrify the paper in any high degree. It requires friction by a

special substance to make the excitement strong. This we learn by experience. It is also experience that has taught us that resinous bodies are best excited by flannel, and vitreous bodies by silk.

Take nothing for granted in this inquiry, and neglect no effort to render your knowledge complete and sure. Try various rubbers, and satisfy yourself that differences like that first observed by Newton exist between them.

Vary also the body rubbed. Excite by friction paraffine and composite candles, resin, sulphur, beeswax, ebonite, and shellac. Also rock-crystal and other vitreous substances, and attract with all of them the balanced lath. A film of collodion, a sheet of vulcanized india-rubber, or brown paper heated before the fire, rubbed briskly with the dry hand, attracts and is attracted by the lath.

Lay bare also the true influence of heat in the case of our rubbed paper. Spread a cold sheet of foolscap on a cold board—on a table, for example. If the air be not very dry, rubbing, even with the india-rubber, will not make them cling together. But is it because they were *hot* that they attracted each other in the first instance? No, for you may heat your board by plunging it into boiling water, and your paper by holding it in a cloud of steam. Thus heated they cannot be made to cling together. The heat really acts by expelling the moisture. Cold weather, if it be only dry, is highly favorable to electric excitation. During frost the whisking of the hand over silk or flannel, or over a cat's back, renders it electrical.

The experiment of the Florentine academicians, whereby they proved the electric attraction of a liquid, is pretty, and worthy of repetition. Fill a very small watch-glass with oil, until the liquid forms a round curved surface, rising a little over the rim of the glass. A strongly excited glass tube, held over the oil, raises not one eminence only, but several, each of which finally discharges a shower of drops against the attracting glass. The effect is shown in fig. 5, where G is the watch-glass on the stand T and R the excited glass tube.*

Cause the excited glass tube to pass

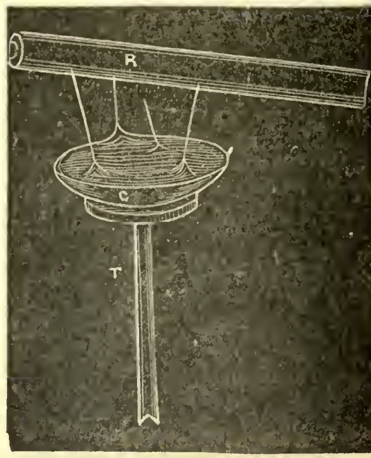


FIG. 5.

close by your face, without touching it. You feel, like Hauksbee, as if a cobweb were drawn over the face. You also sometimes smell a peculiar odor, due to a substance developed by the electricity, and called ozone.

Long ere this, while rubbing your tubes, you will have heard the "hissing" and "crackling" so often referred to by the earlier electricians; and if you have rubbed your glass tube briskly in the dark, you will have seen what they called the "electric fire." Using, instead of a tube, a tall glass jar, rendered hot, a good warm rubber, and vigorous friction, the streams of electric fire are very surprising in the dark.

§ 6. *Discovery of Conduction and Insulation.*

Here I must again refer to that most meritorious philosopher, Stephen Gray. In 1729 he experimented with a glass tube stopped by a cork. When the tube was rubbed, the cork attracted light bodies. Gray states that he was "much surprised" at this, and he "concluded that there was certainly an attractive virtue communicated to the cork." This was the starting point of our knowledge of electric Conduction.

A fir stick 4 inches long, stuck into the cork, was also found by Gray to attract light bodies. He made his sticks

* As a practical measure the watch-glass ought to rest upon a small stand, and not upon a surface of large area. The experiment is particularly well suited for projection on a screen.

longer, but still found a power of attraction at their ends. He then passed on to pack-thread and wire. Hanging a thread S, fig. 6, from the top window of a house, so that the lower end nearly touched the ground, and twisting the upper end of the thread round his glass tube R, on briskly rubbing the tube, light bodies were attracted by the lower end B of the thread.

But Gray's most remarkable experiment was this: He suspended a long hempen line horizontally by loops of pack-thread, but failed to transmit through it the electric power. He then suspended it by loops of silk and succeeded in

FIG. 6.

sending the "attractive virtue" through 765 feet of thread. He at first thought the silk was effectual because it was thin; but on replacing a broken silk loop by a still thinner wire, he obtained no action. Finally, he came to the conclusion that his loops were effectual, not because they were thin but because they were *silk*. This was the starting-point of our knowledge of Insulation.

It is interesting to notice the devotion of some men of science to their work. Dr. Wells, who wrote a beautiful essay, wherein he explained the origin of dew, finished it when he was on the brink of the grave. Stephen Gray was so near dying when his last experiments were made, that he was unable to write out an account of them. On his death-bed, and, indeed, the very day before his death, his description of them was taken from his lips by Dr. Mortimer, Secretary of the Royal Society, and afterward printed in the "Philosophical Transactions."

One word of definition will be useful here. Some substances, as proved by Stephen Gray, possess in a very high degree the power of permitting electricity to pass through them; other substances stop the passage of the electricity. Bodies of the first class are called *conductors;* bodies of the second class are called *insulators.*

You cannot do better than repeat here the experiments of Gray. Push a cork into the open end of your glass tube; rub the tube, carrying the friction up to the end holding the cork. The cork will attract the balanced lath, shown in fig. 4, with which you have already worked so much.

But the excited glass is here so near the end of the cork that you may not feel certain that the observed attraction is that of the cork. You can, however, prove that the cork attracts by its action upon light bodies which cling to it. Stick a pen-holder into the cork and rub the glass tube as before. The free end of the holder will attract the lath. Stick a deal rod three or four feet long into the cork; its free end will attract the lath when the glass tube is excited. In this way you prove to demonstration that the electric power is conveyed along the rod.

§ 7. *The Electroscope.—Further Inquiries on Conduction and Insulation.*

A little addition to our apparatus will now be desirable. You can buy a book of "Dutch metal" for fourpence; and a globular flask like that shown in fig. 7, for sixpence, or at the most a shilling. Find a cork, C, which fits the flask; pass a wire, W, through the cork and bend it near one end at a right angle. Attach by means of wax to the bent arm, which ought to be about three quarters of an inch long, two strips, I, of the Dutch

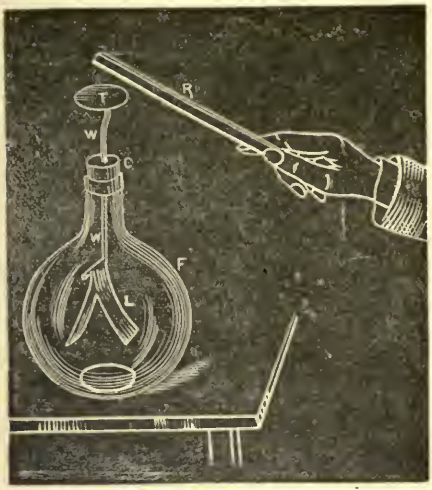


Fig. 7.

metal, about three inches long and from half an inch to three quarters of an inch wide. The strips will hang down face to face, in contact with each other. Stick by sealing-wax upon the other end of the wire a little plate of tin or sheet-zinc, T, about two inches in diameter. In all cases you must be careful so to use your wax as not to interrupt the metallic connection of the various parts of your apparatus, which we will name an *electroscope.* Gold-leaf, instead of Dutch metal, is usually employed for electroscopes. I recommend the "metal" because it is cheaper, and will stand rougher usage.

See that your globular flask is dry and free from dust. Bring your rubbed sealing-wax, R, or your rubbed glass, *near* the little plate of tin, the leaves of Dutch metal open out; withdraw the excited body, the leaves fall together. We shall inquire into the cause of this action immediately. Practise the approach and withdrawal for a little time. Now draw your rubbed sealing-wax or glass along the edge of the tin plate, T. The leaves diverge, and after the sealing-wax or glass is withdrawn they remain divergent. In the first experiment you communicated no electricity to the electroscope; in the second experiment you did. At present I will only ask you to take the opening out of the leaves as a proof that electricity has been communicated to them.

And now we are ready for Gray's experiments in a form different from his. Connect the end of a long wire with the tin plate of the electroscope; coil the other end round your glass tube. Rub the tube briskly, carrying the friction close to the coiled wire. A single stroke of your rubber, if skilfully given, will cause the leaves to diverge. The electricity has obviously passed through the wire to the electroscope.

Substitute for the wire a string of common twine, rub briskly and you will cause the leaves to diverge; but there is a notable difference as regards the promptness of the divergence. You soon satisfy yourself that the electricity passes with greater facility through the wire than through the string. Substitute for the twine a string of silk. No matter how vigorously you rub, you can now produce no divergence. The electricity cannot get through the silk at all.

This is the place to demonstrate in a manner never to be forgotten the influence of moisture. Wet your dry silk string throughout, and squeeze it a little so that the water from it may not trickle over your glass tube. Coil it round the tube as before, and excite the tube. The leaves of the electroscope immediately diverge. The *water* is here the conductor. The influence of moisture was first demonstrated by Du Fay (1733 to 1737), who succeeded in sending electricity through 1256 feet of moist packthread.

It is hardly necessary to point out the meaning of Gray's experiment where he found that, with loops of wire or of pack-thread, he could not send the electricity from end to end of his suspended string. Obviously the electricity escaped in each of these cases through the conducting support to the earth.

My assistant, Mr. Cottrell, who has been working very hard for you and me, has devised an electroscope which we shall frequently employ in our lessons. M, fig. 8, is a little plate of metal, or of wood covered with tin-foil, supported on a rod, G, of glass or of sealing-wax. N is another plate of Dutch metal paper, separated about an inch from M, and attached by sealing wax to the long straw I I′ (broken off in the figure); A A′ is a horizontal pivot formed by a sewing

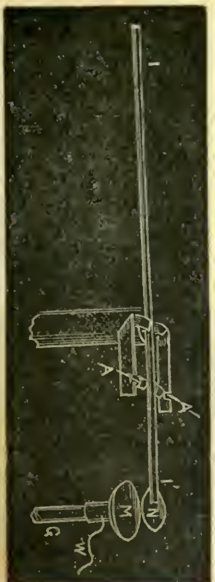


FIG. 8.

needle, and supported on a bent strip of metal, as shown in the figure. By weighting the straw with a little wire near I′, you so balance it that the plate N shall be just lifted away from M. The wire *w*, which may be 100 feet long, proceeds from M to your glass tube, round which it is coiled. A single vigorous stroke of the tube, by the rubber, sends electricity along *w* to M ; N is attracted downward, the other end of the long straw being lifted through a considerable distance. In subsequent figures you will see the complete straw-index, and its modes of application.

A few experiments with either of these instruments will enable you to classify bodies as conductors, semi-conductors, and insulators. Here is a list of a few of each, which, however, differ much among themselves.

Conductors.

The common metals.
Well-burned charcoal.
Concentrated acids.
Solutions of salts.
Rain water.
Linen.
Living vegetables and animals.

Semi-conductors.

Alcohol and ether.	Paper.
Dry wood.	Straw.
Marble.	

Insulators.

Fatty oils.	Silk.
Chalk.	Glass.
India-rubber.	Wax.
Dry paper.	Sulphur.
Hair.	Shellac.

A little reflection will enable you to vary these experiments indefinitely. Rub your excited sealing-wax or glass against the tin plate of your electroscope, and cause the leaves to diverge. Touch the plate with any one of the conductors mentioned in the list ; the electroscope is immediately discharged. Touch it with a semi-conductor ; the leaves fall as before, but less promptly. Touch the plate finally with an insulator, the electricity cannot pass, and the leaves remain unchanged.

§ 8. *Electrics and Non-Electrics.*

For a long period, bodies were divided into *electrics* and *non-electrics*, the former deemed capable of being electrified, the latter not. Thus the amber of the ancients, and the spars, gems, fossils, stones, glasses, and resins, operated on by Dr. Gilbert, were called electrics, while all the metals were called non-electrics. We must now determine the true meaning of this distinction.

Take in succession a piece of brass, of wood coated with tin-foil, a lead bullet, apples, pears, turnips, carrots, cucumbers—uncoated wood not very dry will also answer—in the hand, and strike them briskly with flannel, or the fox's brush ; none of them will attract the balanced lath, fig. 4, or show any other symptom of electric excitement. All of them therefore would have been once called non-electrics.

But suspend them in succession by a string of silk held in the hand, and strike them again ; every one of them will now attract the lath.

Reflect upon the meaning of this experiment. We have introduced an insulator—the silk string—between the hand and the body struck, and we find that by its introduction the non-electric has been converted into an electric.

The meaning is obvious. When held in the hand, though electricity was developed in each case by the friction, it passed immediately through the hand and body to the earth. This transfer being prevented by the silk, the electricity,

once excited, is retained, and the attraction of the lath is the consequence.

In like manner, a brass tube, held in the hand and struck with a fox's brush, shows no attractive power ; but when a stick of sealing-wax, ebonite, or gutta-percha is thrust into the tube as a handle, the striking of the tube at once develops the power of attraction.

And now you see more clearly than you did at first the meaning of the experiment with the heated foolscap and india-rubber. Paper and wood always imbibe a certain amount of moisture from the air. When the rubber was passed over the cold paper electricity was excited, but the paper, being rendered a conductor by its moisture, allowed the electricity to pass away.

Prove all things. Lay your cold foolscap on a cold board supported by dry tumblers ; pass your india-rubber over the paper ; lift it by a loop of silk which has been previously attached to it, for if you touch it it will discharge itself. You will find it electric ; and with it you can charge your electroscope, or attract from a distance your balanced lath.

The human body was ranked among the non-electrics. Make plain to yourself the reason. Stand upon the floor and permit a friend to strike you briskly with the fox's brush. Present your knuckle to the balanced lath, you will find no attraction. Here, however, you stand upon the earth, so that even if electricity had been developed, there is nothing to hinder it from passing away.

But, place upon the ground four warm glass tumblers, and upon the tumblers a board.* Stand upon the board and present your knuckle to the lath. A single stroke of the fox's fur, if skilfully given, will produce attraction. If you stand upon a cake of resin, of ebonite, or upon a sheet of good india-rubber, the effect will be the same. You can also charge your electroscope with this electricity.

Throw a mackintosh over your shoulders and let a friend strike it with the fox's brush, the attractive force is greatly augmented.

After brisk striking, present your knuckle to the knuckle of your friend. A spark will pass between you.

This experiment with the mackintosh further illustrates what you have already frequently observed—namely, that it is not friction alone, but the friction of special substances against each other, that produces electricity.

Thus we prove that non-electrics, like electrics, can be excited, the condition of success being, that an insulator shall be interposed between the non-electric and the earth. It is obvious that the old division into electrics and non-electrics, really meant a division into insulators and conductors.

§ 9. *Electric Repulsions.—Discovery of two Electricities.*

We have hitherto dealt almost exclusively with electric attractions, but in an experiment already referred to (§ 2), Otto von Guericke observed the *repulsion* of a feather by his sulphur globe. I also anticipated matters in the use of our Dutch metal electroscope (§ 7), where the repulsion of the leaves informed us of the arrival of the electricity.

Du Fay, who was the real discoverer here, found a gold-leaf floating in the air to be first attracted and then repelled by the same excited body. He afterward proved that when the floating leaf was repelled by rubbed glass, it was attracted by rubbed resin—and that when it was repelled by rubbed resin it was attracted by rubbed glass. Hence the important announcement, by Du Fay, that there are two kinds of electricity.

The electricity excited on glass was for a time called *vitreous* electricity, while that excited on sealing-wax was called *resinous* electricity. These terms are however improper ; because, by changing the rubber, we can obtain the electricity of sealing-wax upon glass, and the electricity of glass upon sealing-wax.

Roughen, for example, the surface of your glass tube with a grindstone, and rub it with flannel, the electricity of sealing-wax will be found upon the vitreous surface. Rub your sealing-wax with vulcanized india-rubber, the electricity of glass will be found upon the resinous surface. You will be able to prove this immediately.

* Some caution is necessary here. A large class of cheap glass tumblers conduct so freely that they are unfit for this and similar experiments. See § 19.

We now use the term *positive* or *plus* electricity to denote that developed on glass by the friction of silk ; and *negative* or *minus* electricity to denote that developed on sealing-wax by the friction of flannel. These terms are adopted purely for the sake of convenience. There is no reason in nature why the resinous electricity should not be called positive, and the vitreous electricity negative. Once agreed, however, to apply the terms as here fixed, we must adhere to this agreement throughout.

§ 10. *Fundamental Law of Electric Action.*

In all the experiments which we have hitherto made, one of the substances operated on has been electrified by friction, and the other not. But once engaged in inquiries of this description, questions incessantly occur to the mind, the answering of which extends our knowledge and suggests other questions. Suppose, instead of exciting only one of the bodies presented to each other, we were to excite both of them, what would occur ? This is the question which was asked and answered by Du Fay, and which we must now answer for ourselves.

Here your wire loop, fig. 1, comes again into play. Place an unrubbed gutta-percha tube, or a stick of sealing-wax, in the loop, and be sure that it *is* unrubbed—that no electricity adheres to it from former experiments. If it fail to attract light bodies, it is unexcited ; if it attract them, pass your hand over it several times, or, better still, pass it over or through the flame of a spirit lamp. This will remove every trace of electricity. Satisfy yourself that the unrubbed gutta-percha tube is attracted by a rubbed one.

Remove the unrubbed tube from the loop, and excite it with its flannel rubber. One end of the tube is held in your hand and is therefore unexcited. Return the tube to the loop, keeping your eye upon the excited end. Bring a second rubbed tube near the excited end of the suspended one : strong repulsion is the consequence. Drive the suspended tube round and round by this force of repulsion

Bring a rubbed glass tube near the excited end of the gutta-percha tube : strong attraction is the result

Repeat this experiment step by step with two glass tubes. Prove that the rubbed glass tube attracts the unrubbed one. Remove the unrubbed tube from the loop, excite it by its rubber, return it to the loop, and establish the repulsion of glass by glass. Bring rubbed gutta-percha or sealing-wax near the rubbed glass : strong attraction is the consequence.

These experiments lead you directly to the fundamental law of electric action, which is this : *Bodies charged with the same electricity repel each other, while bodies charged with opposite electricities attract each other. Positive repels positive, and attracts negative. Negative repels negative and attracts positive.*

Devise experiments which shall still further illustrate this law. Repeat, for example, Otto von Guericke's experiment. Hang a feather by a silk thread and bring your rubbed glass tube near it : the feather is attracted, touches the tube, charges itself with the electricity of the tube, and is then repelled. Cause it to retreat from the tube in various directions. Du Fay's experiment with the gold-leaf will be repeated and explained further on. See § 18.

Hang your feather by a common thread ; if no insulating substance intervenes between the feather and the earth, you can get no repulsion. Why ? Obviously because the charge of positive electricity communicated by the rod is not retained by the feather, but passes away to the earth. Hence, you have not positive acting against positive at all. Why the neutral body is attracted by the electrified one, will, as already stated, appear by and by.

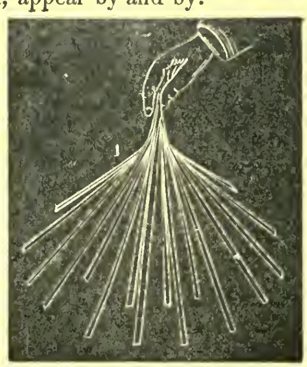


FIG. 11.

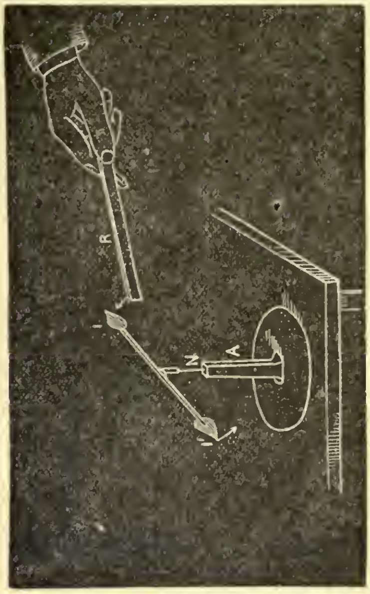


Fig. 9.

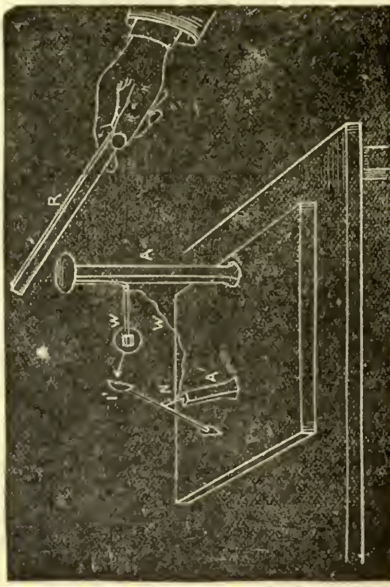


Fig. 10.

Attract your straw needle by your rubbed glass tube. Let the straw strike the tube, so that the one shall rub against the other. The straw accepts the electricity of the tube, and repulsion immediately follows attraction, as shown in fig. 9.

Mr. Cottrell has devised the simple electroscope represented in fig. 10 to show repulsion. A is a stem of sealing-wax with a small circle of tin, T, at the top. W is a bent wire proceeding from T, with a small disk attached to it by wax. I I′ is a little straw index, supported by the needle N, as shown in fig. 10. The stem A′, also of sealing-wax, is not quite vertical, the object being to cause the bit of paper, I′, to rest close to W when the apparatus is not electrified. When electricity is imparted to T, it flows through the wires W and *w*, over both disk and index : immediate repulsion of the straw is the consequence.

No better experiment can be made to illustrate the self-repulsive character of electricity than the following one. Heat your square board (§ 5), and warm, as before, your sheet of foolscap. Spread the paper upon the board, and excite it by the friction of india-rubber. Cut from the sheet two long strips with your penknife. Hold the strips together at one end. Separate them from the board, and lift them into the air : they forcibly drive each other apart, producing a wide divergence.

Cut several strips, so as to form a kind of tassel. Hold them together at one end. Separate them from the board, and lift them into the air : they are driven asunder by the self-repellent electricity, presenting an appearance which may remind you of the hair of Medusa. The effect is represented in fig. 11.*

Another very beautiful experiment fits in here. Let fine silver sand, S, fig. 12, issue in a stream from a glass funnel, through an aperture one eighth of an inch in diameter. Connect the sand in the funnel by a fine wire *w*, fig. 13, with your warm glass tube. Unelectrified, the

* In one of my earliest lectures at the Royal Institution, having rubbed a sheet of foolscap, I was about to lift it bodily from the hot board, and to place it against the wall, when the thought of cutting it into strips, and allowing them to act upon each other, occurred to me. The result, of course, was that above described. Simple and obvious as it was, it gave Faraday, who was present at the time, the most lively pleasure. The simplest experiment, if only suited to its object, delighted him.

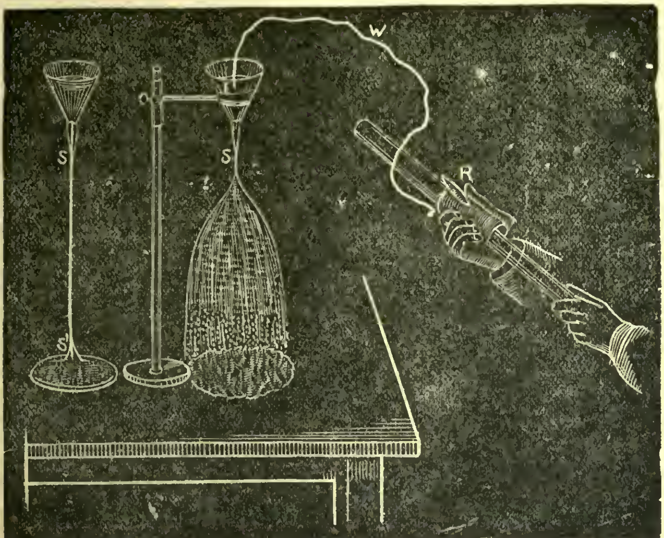


FIG. 12. FIG. 13.

sand particles descend as a continuous stream, s s′, fig. 12, but at every stroke of the rubber they fly asunder, as in fig. 13, through self-repulsion.†

Or let three or four fine fillets of water issue from three or four pin-holes in the bottom of a vessel close to each other. Connect the water of the vessel with your glass tube, and rub as before. The liquid veins are scattered into spray by every stroke of the rubber.

These experiments are best made with "Cottrell's rubber," described in § 24.

And now you must learn to determine with certainty the quality of the electricity with which any body presented to you may be charged. You see immediately that attraction is no sure test, because unelectrified bodies are attracted. Further on (§ 14) you will be able to grapple with another possible source of error in the employment of attraction.

In determining quality, you must ascertain, by trial, the kind of electricity by which the charged body is repelled; if, for example, any electrified body repel, or is repelled by, sealing-wax rubbed with flannel, the electricity of the body is negative; if it repel, or is repelled by, glass, rubbed with silk, its electricity is positive. Du Fay had the sagacity to propose this mode of testing quality.

Apply this test to the strips of foolscap paper excited by the india-rubber. Bring a rubbed gutta-percha tube near the electrified strips, you have strong attraction. Bring a rubbed glass tube between the strips, you have strong repulsion and augmented divergence. Hence, the electricity, being repelled by the positive glass, is itself positive.

§ 11. *Electricity of the Rubber.—Double or "Polar" Character of the Electric Force.*

We have examined the action of each kind of electricity upon itself, and upon the other kind; but hitherto we have kept the rubber out of view. One of the questions which inevitably occur to the inquiring scientific mind would be, How is the rubber affected by the act of friction? Here, as elsewhere, you must examine the subject for yourself, and base your conclusions on the facts you establish.

Test your rubber, then, by your balanced lath. The lath is attracted by the flannel which has rubbed against gutta-percha; and it is attracted by the silk, which has rubbed against glass.

† For these, and also for experiments with the electroscope, the teacher of a large class will find the lime light shadows upon a white screen (or better still, those of the electric light) exceedingly useful. The effects are thus rendered visible to all at once.

Regarding the quality of the electricity of the flannel or of the silk rubber, the attraction of the lath teaches you nothing. But, suspend your rubbed glass tube, and bring the flannel rubber near it : repulsion follows. The silk rubber, on the contrary, attracts the glass tube. Suspend your rubbed gutta-percha tube, and bring the silk rubber near it : repulsion follows. The flannel, on the contrary, attracts the tube.

The conclusion is obvious : the electricity of the flannel is positive, that of the silk is negative.

But the flannel is the rubber of the gutta-percha, whose electricity is negative ; and the silk is the rubber of the glass, whose electricity is positive. Consequently, we have not only proved the rubber to be electrified by the friction, but also proved the electricity of the rubber to be opposite in quality to that of the body rubbed.

All your subsequent experience will verify the statement that the two electricities always go together ; that you cannot excite one of them without at the same time exciting the other, and that the electricity of the rubber, though opposite in quality, is in all cases precisely equal in quantity to that of the body rubbed.

And now we will test these principles by a new experiment. In § 5 we learned that an ebonite comb is electrified by its passage through dry hair. You can readily prove the electricity of the comb to be negative. But the hair is here the rubber, and, in accordance with the principle just laid down, an equal quantity of positive electricity has been excited in the hair. If you stand on the ground uninsulated, the electricity of the hair passes freely through your body to the earth.

But stand upon an insulating stool*—on your board, for example, supported by four warm tumblers—while I, standing on the ground, pass the comb briskly through your hair. I pass it ten, twenty, thirty times, and then ask you to attract your balanced lath. You present your knuckle, but there is no attraction.

Here the comb and the hair soon reach their maximum excitement, beyond which no further development of electricity occurs. Now, though the comb, as shown in § 5, is competent to attract the lath, while your body is here incompetent to do so, this may be because the small quantity of electricity existing in a concentrated form upon the comb becomes, when diffused over the body, too feeble to produce attraction.

Can we not exalt the electricity of your body ? Guided by the principles laid down, let us try to do so. First I pass the unelectrified comb through your hair ; it comes away electrified. After discharging the comb by passing my hand closely over it, I pass it again through the hair. As before, it quits the hair electrified, and I again discharge it. I do this ten or twenty times, always depriving the comb of its electricity after it has quitted the hair. Now present your knuckle to the balanced lath. It is powerfully attracted.

Here, as I have said, the unelectrified comb carried in each case electricity away with it ; but, in accordance with the foregoing principles, it left an equal quantity of the opposite electricity behind it. And though the amount of electricity corresponding to a single charge of the comb, when diffused over the body, proved insensible to our tests, that amount ten or twenty times multiplied became not only sensible, but strong. Indeed, by discharging the comb, and passing it in each case unelectrified through the hair, the insulated human body can be rendered highly electrical.

Near the beginning of this section I said, in rather an off-hand way, that rubbed flannel repels rubbed glass, while rubbed silk repels rubbed gutta-percha. Now, while it is generally easy to obtain the repulsion by the flannel, it is by no means always easy to obtain the repulsion by the silk. Over and over again I have been foiled in my attempts to show this repulsion. I wish you, therefore, to be aware of an infallible method of obtaining it.

Stand on your insulating stool, and rub your glass tube briskly with the amalgamated silk ; hand me the tube. I pass

* A stool with glass legs which, to protect them from the moisture of the air, are usually coated with a solution of shellac. Regarding the attraction of glass for atmospheric humidity, you will call to mind what has been said in § 5.

my hand closely over its surface, removing from that surface nearly the whole of its electricity. I hand you the tube again, and you again excite it. You hand it to me, and I again discharge it. In each case, therefore, you excite an unelectrified glass tube, and in each case the tube leaves behind upon the rubber an amount of negative electricity equal in quantity to the positive carried away. By thus adding charge to charge, the rubber is rendered highly electrical; and even should its insulating power be impaired by the amalgam, it can now afford to yield a portion of its electricity to your hand and body, and still powerfully repel rubbed gutta-percha. The principle, which might be further illustrated, is obviously the same as that applied in the case of the comb.

§ 12. *What is Electricity?*

Thus far we have proceeded from fact to fact, acquiring knowledge of a very valuable kind. But facts alone cannot satisfy us. We seek a knowledge of the *principles* which lie behind the facts, and which are to be discerned by the mind alone. Thus, having spoken as we have done, of electricity passing hither and thither, and of its being prevented from passing, hardly any thoughtful boy or girl can avoid asking what is it that thus passes?—what *is* electricity? Boyle and Newton betrayed their need of an answer to this question when the one imagined his unctuous threads issuing from and returning to the electrified body; and when the other imagined that an elastic fluid existed which penetrated his rubbed glass.

When I say "imagined" I do not intend to represent the notions of these great men as vain fancies. Without imagination we can do nothing here. By imagination I mean the power of picturing mentally things which, though they have an existence as real as that of the world around us, cannot be touched directly by the organs of sense. I mean the purified scientific imagination, without the exercise of which we cannot take a single step into the region of causes and principles.

It was by the exercise of the scientific imagination that Franklin devised the theory of a single electric fluid to explain electrical phenomena. This fluid he supposed to be self-repulsive, and diffused in definite quantities through all bodies. He supposed that when a body has more than its proper share it is positively, when less than its proper share it is negatively electrified. It was by the exercise of the same faculty that Symmer devised the theory of two electric fluids, each self-repulsive, but both mutually attractive.

At first sight Franklin's theory seems by far the simpler of the two. But its simplicity is only apparent. For though Franklin assumed only one fluid, he was obliged to assume three distinct actions. Firstly, he had the self-repulsion of the electric particles. Secondly, the mutual attraction of the electric particles and the ponderable particles of the body through which the electricity was diffused. Thirdly, these two assumptions when strictly followed out lead to the unavoidable conclusion that the material particles also mutually repel each other. Thus the theory is by no means so simple as it appears.

The theory of Symmer, though at first sight the most complicated, is in reality by far the simpler of the two. According to it electrical actions are produced by two fluids, each self-repulsive, but both mutually attractive. These fluids cling to the atoms of matter, and carry the matter to which they cling along with them. Every body, in its natural condition, possesses both fluids in equal quantities. As long as the fluids are mixed together they neutralize each other, the body in which they are thus mixed being in its natural or unelectrical condition.

By friction (and by various other means) these two fluids may be torn asunder, the one clinging by preference to the rubber, the other to the body rubbed.

According to this theory there must always be attraction between the rubber and the body rubbed, because, as we have proved, they are oppositely electrified. This is in fact the case. And mark what I now say. Over and above the common friction, this electrical attraction has to be overcome whenever we rub glass with silk, or sealing-wax with flannel.

You are too young to fully grasp this subject yet; and indeed it would lead us too far away to enter fully into it. But

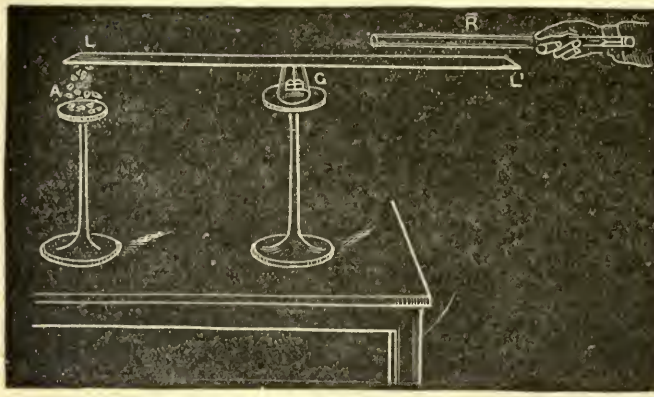


Fig. 14.

Fig. 15.

I will throw out for future reflection the remark, that the overcoming of the ordinary friction produces heat then and there upon the surfaces rubbed, while the force expended in overcoming the electric attraction may be converted into heat which shall appear a thousand miles away from the place where it was generated.

Theoretic conceptions are incessantly checked and corrected by the advance of knowledge, and this theory of electric fluids is doubted by many eminent scientific men. It will, at all events, have to be translated into a form which shall connect it with heat and light, before it can be accepted as complete. Nevertheless, keeping ourselves unpledged to the theory, we shall find it of exceeding service both in unravelling and in connecting together electrical phenomena.

§ 13. *Electric Induction. Definition of the Term.*

We have now to apply the theory of electric fluids to the important subject of electric *induction.*

It was noticed by early observers that *contact* was not necessary to electrical excitement. Otto von Guericke, as we have already seen (§ 2), found that a body brought near his sulphur globe became electrical. By bringing his excited glass tube near one end of a conductor, Stephen Gray attracted light bodies at the other end. He also obtained attraction through the human body. From the human body also Du Fay, to his astonishment, obtained a spark. Canton, in 1753, suspended pith-balls by thread, and holding an excited glass tube, at a considerable distance from them, caused them to diverge. On removing the tube the balls fell together, no permanent charge being imparted to them. Such phenomena were further studied and developed by Wilcke and Æpinus, Coulomb and Poisson.

These and all similar results are embraced by the law, that when an electrified body is brought near an unelectrified conductor, the neutral fluid of the latter is decomposed; one of its constituents being attracted, the other repelled. When the electrified body is withdrawn, the separated electricities flow again together and render the conductor unelectric.

This decomposition of the neutral fluid by the mere presence of an electrified body is called *induction.* It is also called electrification by *influence.*

If, while it is under the influence of the electrified body, the body influenced be touched, the free electricity (which is always of the same kind as that of the influencing body) passes away, the opposite electricity being held captive.

On removing the electrified body the captive electricity is set free, the conductor being charged with electricity opposite in kind to that of the body which

electrified it.

You cannot do better here than repeat Stephen Gray's experiment. Support a small plank or lath, L L′, Fig. 14, upon a warm tumbler, G, and bring under one of its ends, L, and within four or five inches of that end, scraps of light paper or of gold leaf. Excite your glass tube, R, vigorously, and bring it over the other end of the plank, without touching it. The ends may be six or eight feet apart; the light bodies will be attracted. The experiment is easily made, and you are not to rest satisfied till you can make it with ease and certainty.

This is a fit place to repeat that you must keep a close eye upon the tumblers you employ for insulation. Some of them, made of common glass, are hardly to be accounted insulators at all.

§ 14. *Experimental Researches on Electric Induction.*

Our mastery over this subject of induction must be complete; for it underlies all our subsequent inquiries. Without reference to it nothing is to be explained; possessed of it you will enjoy not only a wonderful power of explanation, but of prediction. We will attack it, therefore, with the determination to exhaust it.

And here a slight addition must be made to our apparatus. We must be in a condition to take samples of electricity, and to convey them, with the view of testing them, from place to place. For this purpose the little "carrier," shown in fig. 15, will be found convenient. T is a bit of tin-foil, two or three inches square. A straw stem is stuck on to it by sealing-wax, the lower end of the stem being covered by sealing-wax. To make the insulation sure, the part between R and S′ is wholly of sealing-wax. You can have stems of ebonite, which are stronger, for a few pence; but you can have this one for a fraction of a penny. The end R′ is to be held in the hand; the electrified body is to be touched by T, and the electricity conveyed to an electroscope to be tested.

Touch your rubbed glass rod with T, and then touch your electroscope: the leaves diverge with positive electricity. Touch your rubbed gutta-percha or sealing-wax with T, and then touch your electroscope: the leaves diverge with negative electricity. If the electricity of any body augment the divergence produced by the glass, the electricity of that body is positive. If it augment the divergence produced by the gutta-percha, the electricity is negative. And now we are ready for further work.

Place an egg, E, fig. 16, on its side

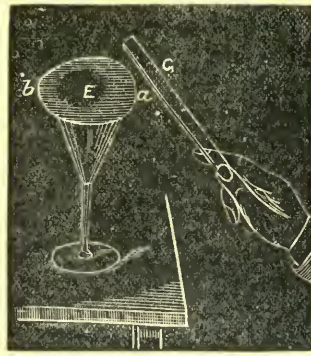


Fig. 16.

upon a dry wine-glass; bring your excited glass tube, G, within an inch or so of the end of the egg. What is the condition of the egg? Its electricity is decomposed; the negative fluid covering the end *a* adjacent to the glass, the positive covering the other end *b*. Remove the glass tube: what occurs? The two electricities flow together and neutrality is restored. Prove this neutrality. Neither a carrier touching the egg, nor the egg itself, has any power to affect your electroscope, or to attract your balanced lath.

Again, bring the excited tube near the egg. Touch its distant part *b* with your carrier. The carrier now attracts the straw (fig. 2) or the balanced lath (fig. 4). It also causes the leaves of your electroscope to diverge. What is the *quality* of the electricity? It repels and is repelled by rubbed glass; the electricity at *b* is therefore positive. Discharge the carrier by touching it, and bring it into contact with the end *a* of the egg nearest to the glass tube. The electricity you take away repels and is repelled by gutta-percha. It is therefore negative. Test the quality also by the electroscope.

While the tube G is near the egg touch the end *b* with your finger; now try to charge the carrier by touching *b*: you cannot do so—the positive electricity has disappeared. Has the negative disap-

peared also? No. Remove the glass tube, and once more touch the egg at *b* by the carrier. It is charged, not with positive, but with negative electricity. Clearly understand this experiment. The neutral electricity of the egg is first decomposed into negative and positive; the former attracted, the latter repelled by the excited glass. The repelled electricity is free to escape, and it has escaped on your touching the egg with your finger. But the attracted electricity cannot escape as long as the influencing tube is held near. On removing the tube which holds the negative fluid in bondage, that fluid immediately diffuses itself over the whole egg. An apple, or a turnip, will answer for these experiments at least as well as an egg.

Discharge the egg by touching it. Re-excite the glass tube and bring it again near. Touch the egg with a wire or with your finger at *a*. Is it the negative at *a*, into which you plunge your finger, that escapes? No such thing. The free positive fluid passes through the negative, and through your finger to the earth. Prove this by removing, first, your finger, and then the glass tube. The egg is charged negatively.

Again; place two eggs, E E, fig. 17,

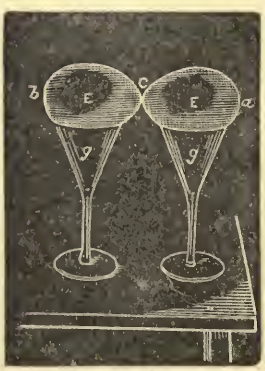


FIG. 17.

lengthwise on two dry wine-glasses, *g g*, and cause two of their ends to touch each other, as at C. Bring your rubbed glass rod near the end *a*, and while it is there separate the eggs by moving one glass away from the other. Withdraw the rod and test both eggs. *a* repels rubbed sealing-wax, and *b* repels rubbed glass; *a* is therefore negative, *b* is positive. The two charges, moreover, exactly neutralize each other in the electroscope. Again bring the eggs together and restore the rubbed tube to its place near *a*. Touch *a* and then separate the eggs. Remove the glass rod and test the eggs. *a* is negative, *b* is neutral. Its electricity has escaped through the finger, though placed at *a*.

Equally good, if not indeed more handy, for these experiments are two apples A A, fig. 18, supported on stems of sealing-wax. A needle is heated and sunk in each case into the stick of wax at the top, and on to the needle the apple is pushed. The sealing-wax stems are stuck on by melting to little foot-boards. By arrangements of this kind you make experiments which are more instructive than those usually made with instruments twenty times more expensive.

Push your researches still farther, and instead of bringing the eggs or apples together place them six feet or so apart,

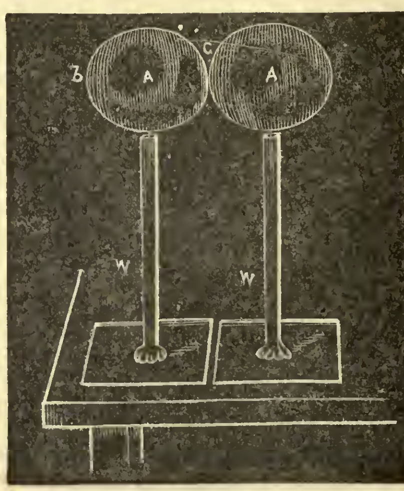


FIG. 18.

and let a light chain, C, fig. 19, or a wire, stretch from one to the other. Two brass balls, or wooden balls covered with tin-foil, supported by tall drinking glasses, GG′, will be better than the eggs for this experiment, for they will bear better the strain of the chain; but you can make the experiment with the eggs, or very readily with the two apples or two turnips. For the present we will suppose the straw-index I I′ not to be there. Rub

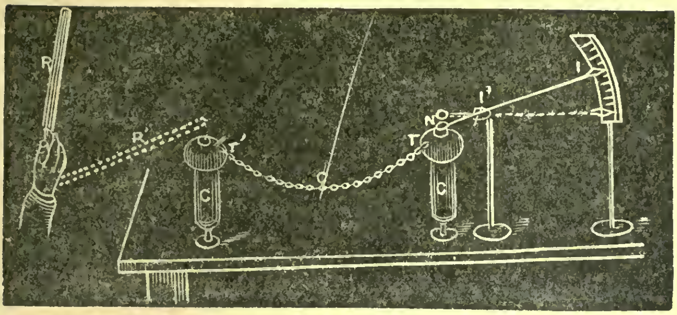


FIG. 19.

your glass tube R, and bring it near one of the balls ; test both : the near one, T′, is negative, the distant one, T, positive. Touch the near one, the positive electricity, which had been driven along the chain to the remotest part of the system, returns along the chain, passes through the negative, which is held captive by the tube, and escapes to the earth. When the tube R is removed, negative electricity overspreads both chain and balls.

In fig. 8 you made the acquaintance of the plate N, and the straw-index I I′, shown on a smaller scale in fig. 19. By their means you immediately see both the effect of the first induction, and the consequence of touching any part of the system with the finger. The plate N rests over the ball or turnip T, the position of the straw-index being that shown by the dots. Bring the rubbed tube near T′ : the end N of the index immediately descends and the other end rises along the graduated scale. Remove the glass rod ; the index I I′ immediately falls. Practice this approach and withdrawal, and observe how promptly the index declares the separation and recomposition of the fluids.

While the tube is near T′, and the end N of the index is attracted, let T′ be touched by the finger. The end N is immediately liberated, for the electricity which pulled it down escapes along the chain and through the finger to the earth. Now remove your excited tube. The captive negative electricity diffuses itself over both balls, and the index is again attracted.

Instead of the chain you may interpose between the balls 100 feet of wire supported by silk loops. This is done in fig. 20, which shows the wire *w* supported by the silk strings S S S. For the ball or turnip T′, fig. 19, the cylinder C, on a glass support G, is substituted, the little table M taking the place of the ball T. Every approach and withdrawal of the rubbed glass tube R is followed obediently by the attraction and liberation of N, and the corresponding motion of the index N I.

Repeat here an experiment, first made

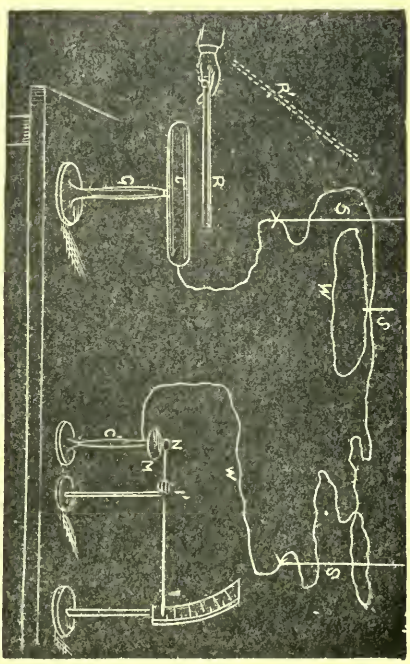


FIG. 20.

by a great electrician named Æpinus. I wish you to make these historic experiments. Insulate an elongated metal conductor, c c′, fig. 21, or one formed of wood coated with tin-foil—even a carrot, cucumber, or parsnip, so that it be insulated, will answer. Let a small weight, w, suspended from a silk string, s, rest on one end of the conductor, and hold

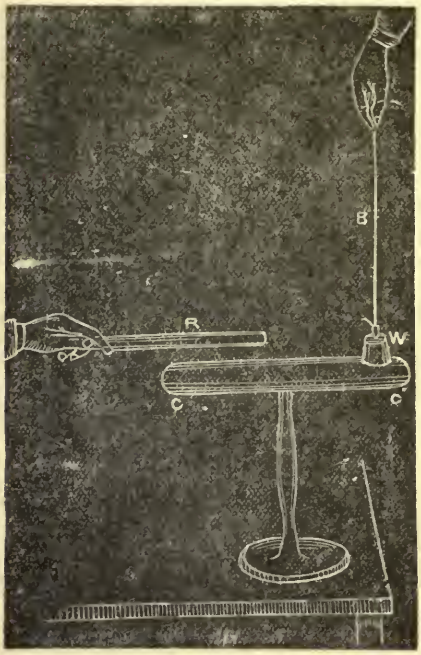


Fig. 21.

your rubbed glass tube, R, over the other end. You can predict beforehand what will occur when you remove the weight. It carries away with it electricity, which repels rubbed glass, and attracts your balanced lath.

Stand on an insulating stool ; or make one by placing a board on four warm tumblers. Present the knuckles of your right hand to the end of the balanced lath, and stretch forth your left arm. There is no attraction. But let a friend or an assistant bring the rubbed glass tube over the left arm ; the lath immediately follows the right hand.

Touch the lath, or any other uninsulated body ; the "attractive virtue," as it was called by Gray, disappears. After this, as long as the excited tube is held over the arm there is no attraction. But when the tube is removed the attractive power of the hand is restored. Here the first attraction was by positive electricity driven to the right hand from the left, and the second attraction by negative electricity, liberated by the removal of the glass rod. Experiment proves the logic of theory to be without a flaw.

Stand on an insulating stool, and place your right hand on the electroscope ; there is no action. Stretch forth the left arm and permit an assistant alternately to bring near, and to withdraw, an excited glass tube. The gold leaves open and collapse in similar alternation. At every approach, positive electricity is driven over the gold leaves ; at every withdrawal, the equilibrium is restored.

We are now in a condition to repeat, with ease, the experiment of Du Fay mentioned in § 13. A board is supported by four silk ropes, and on the board is stretched a boy. Bring his forehead, or better still his nose, under the end of your straw-index I I′, fig. 22. Then bring down over his legs your rubbed glass tube ; instantly the end I′ is attracted and the end I rises along the graduated scale. Before the end I′ comes into contact with the nose or forehead a spark passes between it and the boy.

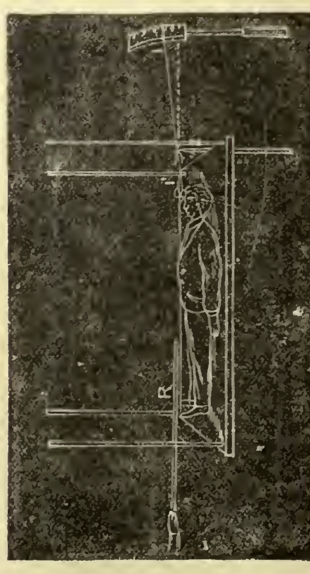


Fig. 22.

I will now ask you to charge your Dutch metal electroscope (fig. 7) positively by rubbed gutta-percha, and to charge it negatively by rubbed glass. A moment's reflection will enable you to do it. You bring your excited body near: the same electricity as that of the excited body is driven over the leaves, and they diverge by repulsion. Touch the electroscope, the leaves collapse. Withdraw your finger, and withdraw afterwards the excited body: the leaves then diverge with the opposite electricity.

The simplest way of testing the quality of electricity is to charge the electroscope with electricity of a known kind. If, on the *approach* of the body to be tested, the leaves diverge still wider, the leaves and the body are similarly electrified. The reason is obvious.

Omitting the last experiment, the wealth of knowledge which these researches involve might be placed within any intelligent boy's reach by the wise expenditure of half-a-crown.

Once firmly possessed of the principle of induction and versed in its application, the difficulties of our subject will melt away before us. In fact our subsequent work will consist mainly in unravelling phenomena by the aid of this principle.

Without a knowledge of this principle we could render no account of the attraction of neutral bodies by our excited tubes. In reality the attracted bodies are *not* neutral: they are first electrified by influence, and it is because they are thus electrified that they are attracted.

This is the place to refer more fully to a point already alluded to. Neutral bodies, as just stated, are attracted, because they are really converted into electrified bodies by induction. Suppose a body to be feebly electrified positively, and that you bring your rubbed glass tube to bear upon the body. You clearly see that the induced negative electricity may be strong enough to mask and overcome the weak positive charge possessed by the body. We should thus have two bodies electrified alike, attracting each other. This is the danger against which I promised to warn you in § 10, where the test of attraction was rejected.

We will now apply the principle of induction to explain a very beautiful invention, made known by the celebrated Volta in 1775.

§ 15. *The Electrophorus.*

Cut a circle, T, fig. 23, 6 inches in diameter out of sheet zinc, or out of common tin. Heat it at its centre by the

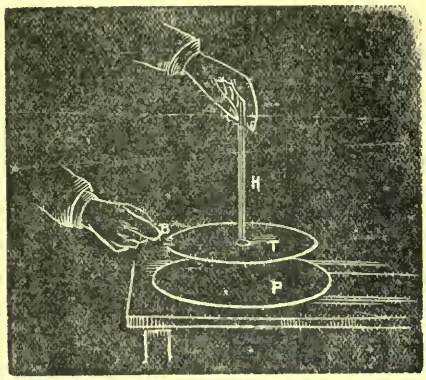


FIG. 23.

flame of a spirit-lamp or of a candle. Attach to it there a stick of sealing-wax, H, which, when the metal cools, is to serve as an insulating handle.—You have now the *lid* of the electrophorus. A resinous surface, or what is simpler a sheet of vulcanized india-rubber, P, or even of hot brown paper, will answer for the *plate* of the electrophorus.

Rub your "plate" with flannel, or whisk it briskly with a fox's brush. It is thereby negatively electrified. Place the "lid" of your electrophorus on the excited surface: it touches it at a few points only. For the most part lid and plate are separated by a film of air.

The excited surface acts by induction across this film upon the lid, attracting its positive and repelling its negative electricity. You have in fact in the lid two layers of electricity, the lower one, which is "bound," positive; the upper one, which is "free," negative. Lift the lid: the electricities flow again together; neutrality is restored, and your lid fails to attract your balanced lath.

Once more place the lid upon the excited surface: touch it with the finger. What occurs? You ought to know. The free electricity, which is negative, will escape through your body to the earth, leaving the chained positive behind.

Now lift the lid by the handle: what is its condition? Again I say you ought

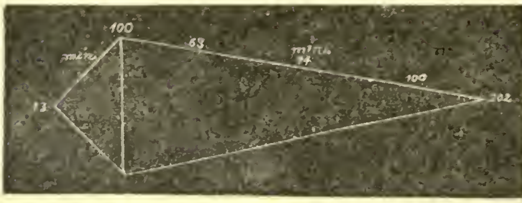


FIG. 24.

to know. It is covered with free positive electricity. If it be presented to the lath it will strongly attract it : if it be presented to the knuckle it will yield a spark.

A smooth half-crown, or a penny, will answer for this experiment. Stick to the coin an inch of sealing-wax as an insulating handle : bring it down upon the excited india-rubber : touch it, lift it, and present it to your lath. The lath may be six or eight feet long, three inches wide and half an inch thick ; the little electrophorus lid, formed by the half crown, will pull it round and round. The experiment is a very impressive one.

Scrutinize your instrument still further. Let the end of a thin wire rest upon the lid of your electrophorus, under a little weight if necessary ; and connect the other end of the wire with the electroscope. As you lower the lid down toward the excited plate of the electrophorus, what must occur? The power of prevision now belongs to you and you must exercise it. The repelled electricity will flow over the leaves of the electroscope, causing them to diverge. Lift the lid, they collapse. Lower and raise the lid several times, and observe the corresponding rhythmic action of the electroscope leaves.

A little knob of sealing-wax, B, coated with tin-foil, or indeed any knob with a conducting surface, stuck to the lid of the electrophorus, will enable you to obtain a better spark. The reason of this will immediately appear.

More than half the value of your present labor consists in arranging each experiment in thought before it is realized in fact ; and more than half the delight of your work will consist in observing the verification of what you have foreseen and predicted.

§ 16. *Action of Points and Flames.*

The course of exposition proceeds naturally from the electrophorus to the electrical machine. But before we take up the machine we must make our minds clear regarding the manner in which electricity diffuses itself over conductors, and more especially over elongated and pointed conductors.

Rub your glass tube and draw it over an insulated sphere of metal—of wood covered with tin-foil, or indeed any other insulated spherical conductor. Repeat the process several times, so as to impart a good charge to the sphere. Touch the charged sphere with your carrier, and transfer the charge to the electroscope. Note the divergence of the leaves. Discharge the electroscope, and repeat the experiment, touching, however, some other point of the sphere. The electroscope shows sensibly the same amount of divergence. Even when the greatest exactness of the most practised experimenter is brought into play, the spherical conductor is found to be equally charged at all points of its surface. You may figure the electric fluid as a little ocean encompassing the sphere, and of the same depth everywhere.

But supposing the conductor, instead of being a sphere, to be a cube, an elongated cylinder, a cone, or a disk. The depth, or as it is sometimes called the *density*, of the electricity, will not be everywhere the same. The corners of the cube will impart a stronger charge to your carrier than the sides. The end of the cylinder will impart a stronger charge than its middle. The edge of the disk will impart a stronger charge than its flat surface. The apex or point of the cone will impart a stronger charge than its curved surface or its base.

You can satisfy yourself of the truth of all this in a rough, but certain way, by charging, after the sphere, a turnip cut into the

form of a cube ; or a cigar-box coated with tin-foil ; a metal cylinder, or a wooden one coated with tin-foil ; a disk of tin or of sheet zinc ; a carrot or parsnip with its natural shape improved so as to make it a sharp cone. You will find the charge imparted to the carrier by the sharp corners and points of such bodies, when electrified, to be greater than that communicated by the gently rounded or flat surfaces. The difference may not be great, but it will be distinct. Indeed an egg laid on its side, as we have already used it in our experiments on induction (fig. 16), yields a stronger charge from its ends than from its middle.

Fig. 25.

Let me place before you an example of this distribution, taken from the excellent work on "Frictional Electricity" by Professor Riess of Berlin. Two cones, fig. 24, are placed together base to base. Calling the strength of the charge along the circular edge where the two bases join each other 100, the charge at the apex of the blunter cone is 133 ; and at the apex of the sharper one 202. The other numbers give the charges taken from the points where they are placed. Fig. 25, moreover, represents a cube with a cone placed upon it. The charge on the face of the cube being 1, the charges at the corners of the cube and at the apex of the cone are given by the other numbers; they are all far in excess of the electricity on the flat surface.

Riess found that he could deduce with great accuracy the *sharpness* of a point, from the charge which it imparted. He compared in this way the sharpness of various thorns, with that of a fine English sewing needle. The following is the result :—Euphorbia thorn was sharper than the needle ; gooseberry thorn of the same sharpness as the needle ; while cactus, blackthorn, and rose, fell more and more behind the needle in sharpness. Calling, for example, the charge obtained from euphorbia 90 ; that obtained from the needle was 80, and from the rose only 53.

Considering that each electricity is self-repulsive, and that it heaps itself up upon a point, in the manner here shown, you will have little difficulty in conceiving that when the charge of a conductor carrying a point is sufficiently strong, the electricity will finally disperse itself by streaming from the point.

The following experiments are theoretically important : Attach a stick of sealing-wax to a small plate of tin or of wood, so that the stick may stand upright. Heat a needle and insert it into the top of the stick of wax ; on this needle mount horizontally a carrot. You have thus an insulated conductor. Stick into your carrot at one of its ends a sewing needle ; and hold for an instant your rubbed glass tube in front of this needle without touching it. What occurs ? The negative electricity of the carrot is immediately discharged from the point against the glass tube. Remove the tube, test the carrot : it is positively electrified.

And now for another experiment, not so easily made, but still certain to succeed if you are careful. Excite your glass rod, turn your needle away from it, and bring the rod near the other end of the carrot. What occurs ? The positive electricity is now repelled to the point, from which it will stream into the air. Remove the rod and test the carrot : it is negatively electrified.

Again turn the point toward you, and place in front of it a plate of dry glass, wax, resin, shellac, paraffin, gutta-percha or any other insulator. Pass your rubbed glass tube once downwards or upwards, the insulating plate being between the excited tube and the point. The point will discharge its electricity against the insulating plate, which on trial will be found negatively electrified.

§ 17. *The Electrical Machine.*

An electrical machine consists of two principal parts : the insulator which is

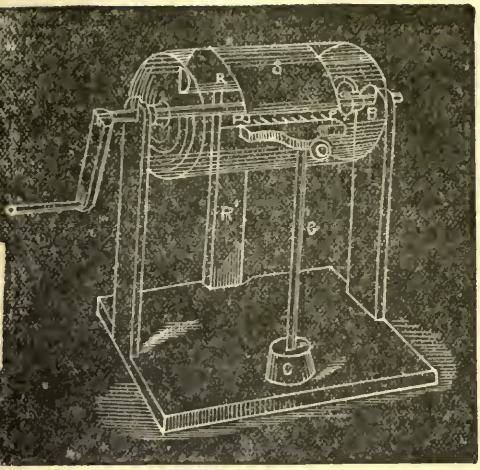


FIG. 26.

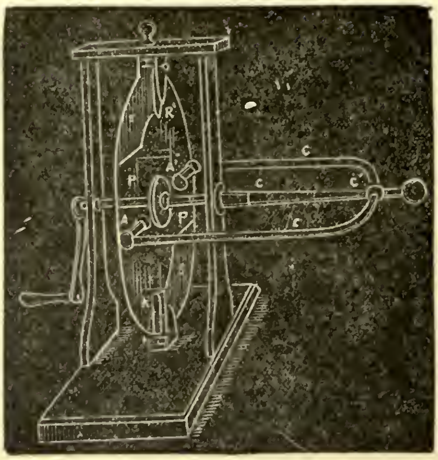


FIG. 27.

excited by friction, and the "prime con ductor."

The sulphur sphere of Otto von Guericke was, as already stated, the first electrical machine. The hand was the rubber, and indeed it long continued to be so. For the sulphur sphere, Hauksbee and Winckler substituted globes of glass. Boze of Wittenberg (1741) added the prime conductor, which was at fir t a tin tube supported by resin, or suspended by silk. Soon afterward Gordon substituted a glass cylinder for the globe. It was sometimes mounted vertically, sometimes horizontally. Gordon so intensified his discharges as to be able to kill small birds with them. In 1760 Planta introduced the plate machine now commonly in use.

Mr. Cottrell has constructed for these Lessons the small cylinder machine shown in fig. 26. The glass cylinder is about 7 inches long and 4 inches in diameter; its cost is eighteen pence. Through the cylinder passes tightly, as an axis, a piece of lath, rendered secure by sealing-wax where it enters and where it quits the cylinder. G is a glass rod supporting the conductor C, which is a piece of lath coated with tin-foil. Into the lath is driven the series of pin points, P, P. The rubber R, is seen at the further side of the cylinder, supported by the upright lath R′, and caused to press against the glass. S′ is a flap of silk attached to the rubber. When the handle is turned sparks may be taken, or a Leyden jar charged at the knob C.

A plate machine is shown in fig. 27. P is the plate, which turns on an axis passing through its centre; R and R′ are two rubbers which clasp the plate, with the flaps of silk S S′ attached to them. A and A′ are rows of points forming part of the prime conductor, C. G G′ is an insulating rod of glass, which cuts off the connection between the conductor and the handle of the machine.

The prime conductor is charged in the following manner. When the glass plate is turned, as it passes each rubber it is positively electrified. Facing the electrified glass is the row of points, placed midway between the two rubbers. On these points the glass acts by induction, attracting the negative and repelling the positive. In accordance with the principles already explained in § 16, the negative electricity streams from the points against the excited glass, which then passes on neutralized to the next rubber, where it is again excited.

Thus the prime conductor is charged, not by the direct communication to it of positive electricity, but by depriving it of its negative.

If when the conductor is charged you bring the knuckle near it, the electricity passes from the conductor to the knuckle in the form of a spark.

Take this spark with the blunt knuckle while the machine is being turned; and

FIG. 28.

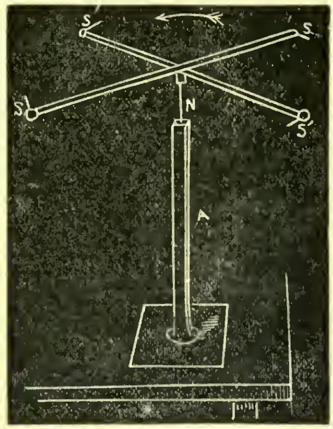


FIG. 29.

then try the effect of presenting the finger ends, instead of the knuckle, to the conductor. The spark falls exceedingly in brilliancy. Substitute for the finger ends a needle point : you fail to get a spark at all. To obtain a good spark the electricity upon the prime conductor must reach a sufficient density (or tension as it is sometimes called) ; and to secure this no points from which the electricity can stream out must exist on the conductor, or be presented to it. All parts of the conductor are therefore carefully rounded off, sharp points and edges being avoided.

It is usual to attach to the conductor an electroscope consisting of an upright metal stem, A C, fig. 28, to which a straw with a pith ball, B, at its free end, is attached. The straw turns loosely upon a pivot at C. The electricity passing from the conductor is diffused over the whole electroscope, and the straw and stem being both positively electrified, repel each other. The straw, being the movable body, flies away. The amount of the divergence is measured upon a graduated arc.

§ 18. *Further Experiments on the Action of Points.—The Electric Mill.—The Golden Fish.—Lightning Conductors.*

If no point exist on the conductor, a single turn of the handle of the machine usually suffices to cause the straw to stand out at a large angle to the stem. If, on the contrary, a point be attached to the conductor, you cannot produce a large divergence, because the electricity, as fast as it is generated, is dispersed by the point. The same effect is observed when you present a point to the conductor. The conductor acts by induction upon the point, causing the negative electricity to stream from it against the conductor, which is thus neutralized almost as fast as it is charged. Flames and glowing embers act like points ; they also rapidly discharge electricity.

The electricity escaping from a point or flame into the air renders the air self repulsive. The consequence is that when the hand is placed over a point mounted on the prime conductor of a machine in good action, a cold blast is distinctly felt. Dr. Watson noticed this blast from a flame placed on an electrified conductor ; while Wilson noticed the blast from a point. Jallabert and the Abbé Nollet also observed and described the influence of points and flames. The blast is called the "electric wind." Wilson moved bodies by its action : Faraday caused it to depress the surface of a liquid : Hamilton employed the *reaction* of the electric wind to make pointed wires rotate. The "wind" was also found to promote evaporation.

Hamilton's apparatus is called the "electric mill." Make one for yourself thus : Place two straws s s′, s s′, fig. 29, about eight inches long, across each other at a right angle. Stick them together at their centres by a bit of sealing-wax. Pass a fine wire through each straw, and bend it where it issues from the straw, so as to form a little pointed arm perpen-

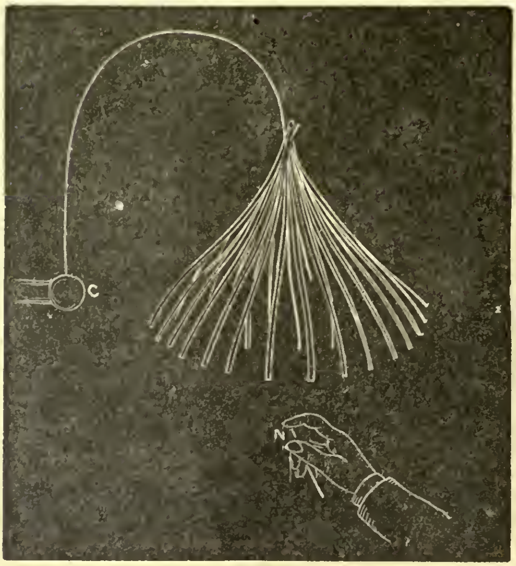


FIG. 30.

dicular to the straw, and from half an inch to three quarters of an inch long. It is easy, by means of a bit of cork or sealing-wax, to fix the wire so that the little bent arms shall point not upward or downward, but sideways, when the cross is horizontal. The points of sewing needles may also be employed for the bent arms. A little bit of straw stuck into the cross at the centre forms a cap. This slips over a sewing needle, N, supported by a stick of sealing-wax, A. Connect the sewing needle with the electric machine, and turn. A wind of a certain force is discharged from every point, and the cross is urged round with the same force in the opposite direction.

You might easily, of course, so arrange the points that the wind from some of them would neutralize the wind from others. But the little pointed arms are to be so bent that the reaction in every case shall not oppose but add itself to the others.

The following experiments will yield you important information regarding the action of points. Stand, as you have so often done before, upon a board supported by four warm tumblers. Hold a small sewing needle, with its point defended by the forefinger of your right hand, toward your Dutch metal electroscope. Place your left hand on the prime conductor of your machine. Let the handle

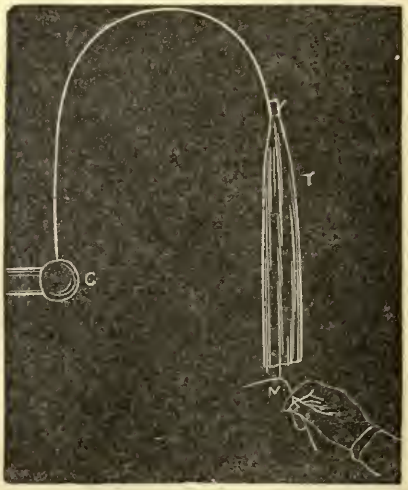


FIG. 31.

be turned by a friend or an assistant : the leaves of the electroscope open out a little. Uncover the needle point by the removal of your finger ; the leaves at once fly violently apart.

Mount a stout wire upright on the conductor, C, fig. 30, of your machine ; or support the wire by sealing-wax, gutta-

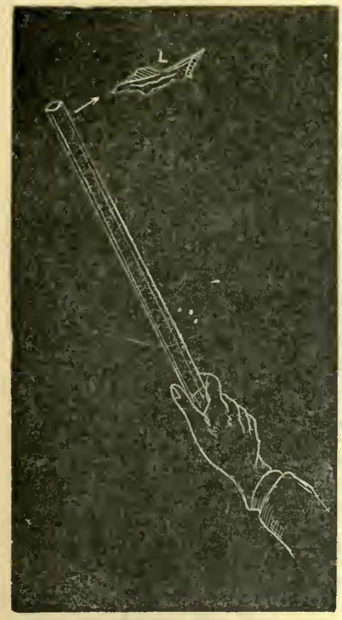


FIG. 32.

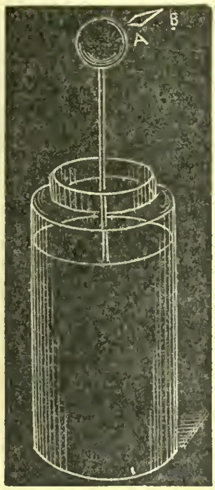


FIG. 33.

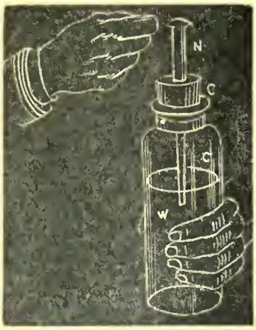


FIG. 34.

percha or glass, at a distance from the conductor, and conneet both by a fine wire. Bend your stout wire into a hook, and hang from it a tassel, T, composed of many strips of light tissue paper. Work the machine. Electricity from the conductor flows over the tassel, and the strips diverge. Hold your closed fist toward the tassel, the strips of paper stretch toward it. Hold the needle, defended by the finger, toward the tassel : attraction also ensues. Uncover the needle without moving the hand ; the strips retreat as if blown away by a wind. Holding the needle, N, fig. 31, upright underneath the tassel, its strips discharge themselves and collapse utterly.

And now repeat Du Fay's experiment which led to the discovery of two electricities. Excite your glass tube, and hold it in readiness while a friend or an assistant liberates a real gold or silver leaf in the air. Bring the tube near the leaf : it plunges toward the tube, stops suddenly, and then flies away. You may chase it round the room for hours without permitting it to reach the ground. The leaf is first acted upon inductively by the tube. It is powerfully attracted for a moment, and rushes toward the tube. But from its thin edges and corners the negative electricity streams forth, leaving the leaf positively electrified. Repulsion then sets in, because tube and leaf are electrified alike, as shown in fig. 32. The retreat of the tassel in the last experiment is due to a similar cause.

There is also a discharge of positive electricity into the air from the more distant portions of the gold-leaf, to which that electricity is repelled. Both discharges are accompanied by an electric wind. It is possible to give the gold-leaf a shape which shall enable it to float securely in the air, by the reaction of the two winds issuing from its opposite ends. This is Franklin's experiment of the Golden Fish. It was first made with the charged conductor of an electrical machine. M. Srtsezek revived it in a more convenient form, using instead of the conductor the knob of a charged Leyden jar. You may walk round a room with the jar in your hand ; the "fish" will obediently follow in the air an inch or two, or even three inches, from the knob. See A B, fig. 33. Even a hasty motion of the jar will not shake it away.

Well-pointed lightning conductors, when acted on by a thunder cloud, discharge their induced electricity against the cloud. Franklin saw this with great clearness, and illustrated it with great ingenuity. The under side of a thunder cloud, when viewed horizontally, he observed to be ragged, composed, in fact, of fragments one below the other, sometimes reaching near the earth. These he regarded as so many stepping-stones which assist in conducting the stroke of the cloud. To represent these by experiment he took two or three locks of fine loose cotton, tied them in a row, and hung them from his prime conductor. When this was excited the locks stretched downward toward the earth; but by presenting a sharp point erect under the lowest bunch of cotton, it shrunk upward to that above it, nor did the shrinking cease till all the locks had retreated to the prime conductor itself. "May not," says Franklin, "the small electrified cloud, whose equilibrium with the earth is so soon restored by the point, rise up to the main body, and by that means occasion so large a vacancy that the grand cloud cannot strike in that place?"

§ 19. *History of the Leyden Jar.—The Leyden Battery.*

The next discovery which we have to master throws all former ones into the shade. It was first announced in a letter addressed on the 4th of November, 1745, to Dr. Lieberkühn, of Berlin, by Kleist, a clergyman of Cammin, in Pomerania. By means of a cork, C, fig. 34, he fixed a nail, N, in a phial, G, into which he had poured a little mercury, spirits, or water, W. On electrifying the nail he was able to pass from one room into another with the phial in his hand and to ignite spirits of wine with it. "If," said he, "while it is electrifying I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders."

In the following year Cunæus of Leyden made substantially the same discovery. It caused great wonder and dread, which arose chiefly from the excited imagination. Musschenbroek felt the shock, and declared in a letter to a friend that he would not take a second one for the crown of France. Bleeding at the nose, ardent fever, a heaviness of head which endured for days, were all ascribed to the shock. Boze wished that he might die of it, so that he might enjoy the honor of having his death chronicled in the Paris "Academy of Sciences." Kleist missed the explanation of the phenomenon; while the Leyden philosophers correctly stated the conditions necessary to the success of the experiment. Hence the phial received the name of the Leyden phial, or Leyden jar.

The discovery of Kleist and Cunæus excited the most profound interest, and the subject was explored in all directions. Wilson in 1746 filled a phial partially with water, and plunged it into water, so as to bring the water surfaces, within and without the phial, to the same level. On charging such a phial the strength of the shock was found greater than had been observed before.

Two years subsequently Dr. Watson and Dr. Bevis noticed how the charge grew stronger as the area of the conductor in contact with the outer surface of the phial increased. They substituted shot for water inside the jar, and obtained substantially the same effect. Dr. Bevis then coated a plate of glass on both sides with silver foil, to within about an inch of the edge, and obtained from it discharges as strong as those obtained from a phial containing half a pint of water. Finally Dr. Watson coated his phial inside and out with silver foil. By these steps the Leyden jar reached the form which it possesses to-day.

It is easy to repeat the experiment of Dr. Bevis. Procure a glass plate nine inches square; cover it on both sides, as he did, with tin-foil seven inches square, leaving the rim uncovered. Connect one side with the earth, and the other with the machine. Charge and discharge: you obtain a brilliant spark.

In our experiment with the Golden Fish (fig. 33), we employed a common form of the Leyden jar, only with the difference that to get to a sufficient distance from the glass, so as to avoid the attraction of the fish by the jar itself, the knob was placed higher than usual. But with a good flint-glass tumbler, a piece of tin-foil, and a bit of stout wire, you can

make a jar for yourself. Bad glass, remember, is not rare. In fig. 35 you have such a jar. T is the outer T′ the inner coating, reaching to within an inch of the edge of the tumbler G. W is the

Fig. 35.

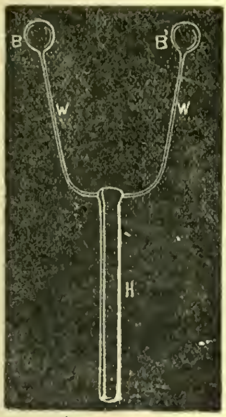


Fig. 36.

wire fastened below by wax, and surmounted by a knob, which may be of metal, or of wax or wood, coated with tin-foil. In charging the jar you connect the outer coating with the earth—say with a gas-pipe or a water-pipe—and present the knob to the conductor of your machine. A few turns will charge the jar. It is discharged by laying one knob of a "discharger" against the outer coating, and causing the other knob to approach the knob of the jar. Before contact, the electricity flies from knob to knob in the form of a spark.

A "discharger" suited to our means and purposes is shown in fig. 36. H is a stick of sealing-wax, or, better still, of ebonite; W W a stout wire bent as in the figure, and ending in the knobs B B′. These may be of wax coated with tin-foil. Any other light conducting knobs would of course answer. The insulating handle H protects you effectually from the shock.

You must render yourself expert in the use of the discharger. The mode of using it is shown in fig. 37.

By augmenting the size of a Leyden jar we render it capable of accepting a larger charge of electricity. But there is a limit to the size of a jar. When therefore, larger charges are required than a single jar can furnish, we make use of a number of jars. In fig. 38 nine of them are shown. All their interior coatings are united together by brass rods, while all the outer coatings rest upon a metal surface in free communication with the earth.

This combination of Leyden jars constitutes the *Leyden Battery*, the effect of which is equal to that of a single jar of nine times the size of one of the jars.

§ 20. *Explanation of the Leyden Jar.*

The principles of electrical induction

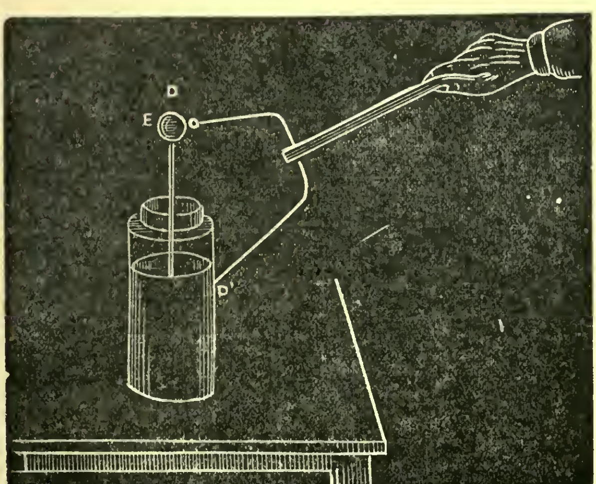


Fig. 37.

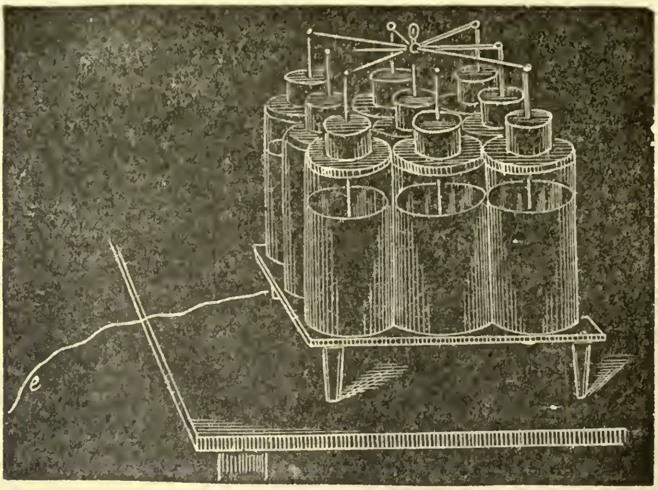


FIG. 38.

with which you are now so familiar will enable you to thoroughly analyze and understand the action of the Leyden jar. In charging the jar the outer coating is connected with the earth, and the inner coating with the electrical machine. Let the machine, as usual, be of glass yielding positive electricity. When it is worked the electricity poured into the jar acts inductively across the glass upon the outer coating, attracting its negative and repelling its positive to the earth. Two mutually attractive electric layers are thus in presence of each other, being separated merely by the glass. When the machine is in good order and the glass of the jar is thin, the attraction may be rendered strong enough to perforate the jar. By means of the discharger the opposite electricities are enabled to unite in the form of a spark.

Franklin saw and announced with clearness the escape of the electricity from the outer coating of the jar. His statement is that whatever be the quantity of the "electric fire" thrown into the jar, an equal quantity was dislodged from the outside. We have now to prove by actual experiment that this explanation is correct.

Place your Leyden jar upon a table, and connect the outer coating with your electroscope. There is no divergence of the leaves when electricity is poured into the jar.

But here the outer coating is connected through the table with the earth. Let us cut off this communication by an insulator. Place the jar upon a board supported by warm tumblers, or upon a piece of vulcanized india-rubber cloth, and again connect the outer coating with the electroscope. The moment electricity is communicated to the knob of the jar the leaves of Dutch metal diverge. Detach the wire by your discharger and test the quality of the electricity—it is positive, as theory declares it must be.

Consider now the experiment of Kleist and Cunæus (fig. 34). You will, I doubt not, penetrate its meaning. You will see that in their case the *hand* formed the outer coating of the jar. When electricity was communicated through the nail to the water within, that electricity acted across the glass inductively upon the hand, attracting the one fluid and repelling the other to the earth.

Again, I say, prove all things; and what is here affirmed may be proved by the following beautiful and conclusive experiment: Stand on your board, I I′ fig. 39, insulated by its four tumblers; or upon a sheet of gutta-percha, or vulcanized india-rubber. Seize the old Leyden phial, J, with your left hand, and present the knuckle of your right hand to your balanced lath, L′ L. When electricity is communicated to the nail, the lath is immediately attracted by the knuckle. Or touch your electroscope with your right hand; when the phial is charged

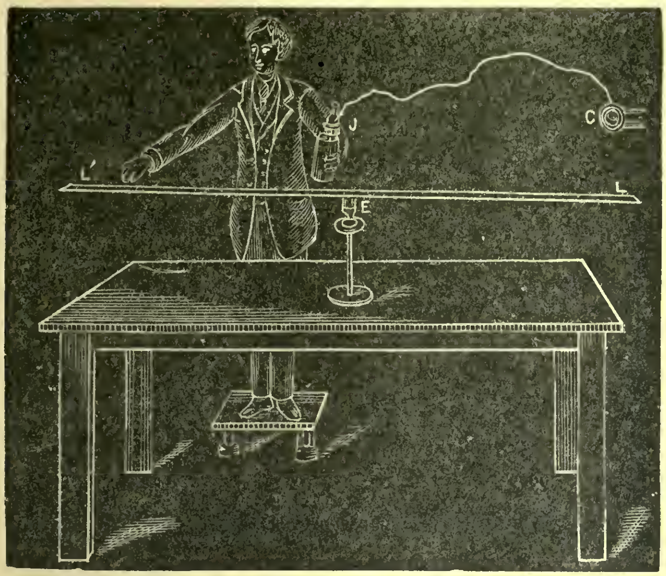


FIG. 39.

the leaves immediately diverge, by the electricity driven from your left hand to the electroscope.

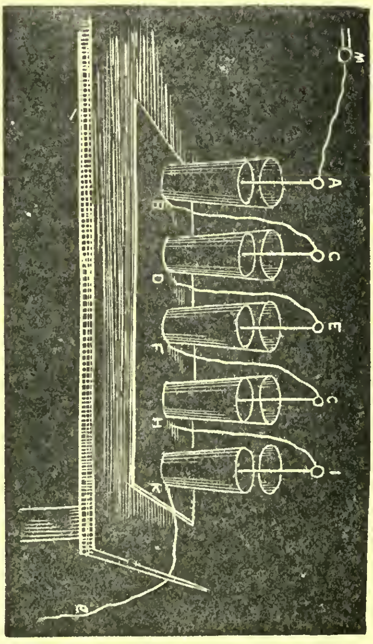
Here the nail may be electrified either by connecting it with the prime conductor of the machine, or by rubbing it with an excited glass rod. Indeed, I should prefer your resorting to the simplest and cheapest means in making these experiments.

§ 21. *Franklin's Cascade Battery.*

As a thoughtful and reflective boy or girl you cannot, I think, help wondering at the power which your thorough mastery of the principles of induction gives you over these wonderful and complicated phenomena. By those principles the various facts of our science are bound together into an organic whole. But we have not yet exhausted the fruitfulness of this principle.

Consider the following problem. Usually we allow the electricity of the outer coating to escape to the earth. Suppose we try to utilize it. Place, then, your jar, A B, fig. 40, upon vulcanized india-rubber, and connect by a wire B C its outer coating with the knob or inner coating of a second jar C D. What will occur when the first jar is charged? Why, the second one will be charged also by the electricity which has escaped from the outer coating of the first. And suppose you connect the outer coating of the second insulated jar with the inner

FIG. 40.



coating of a third, E F; what occurs? The third jar will obviously be charged with the electricity repelled from the outer coating of the second. Of course we need not stop here. We may have a long series of insulated jars, the outer coating of each being connected with the inner coating of the next succeeding one. Connect the outer coating of the last jar I K by a wire *e* with the earth, and charge the first jar. You charge thereby the entire series of jars. In this simple way you master practically, and grasp the theory of Franklin's celebrated "*cascade battery*."

You must see that before making this important experiment you could really have predicted what would occur. This power of prevision is one of the most striking characteristics of science.

§ 22. *Novel Leyden Jars of the Simplest Form.*

Possessed of its principles, we can reduce the Leyden jar to far simpler forms than any hitherto dealt with. Spread a sheet of tin-foil smoothly upon a table, and lay upon the foil a pane of glass. Remember that the glass, as usual, must be dry. Stick on to the glass by sealing-wax two loops of narrow silk ribbon, by which the pane may be lifted; and then lay smoothly upon the glass a second sheet of tin-foil, less than the pane in size, leaving a rim of uncovered glass all round. Carry a fine wire from the upper sheet of tin-foil to your electroscope. A little weight will keep the end of the wire attached to the tin-foil.

Rub this weight with your excited glass tube, two or three times if necessary, until you see a slight divergence of the Dutch metal leaves. Or connecting the weight with the conductor of your machine, turn very carefully until the slight divergence is observed. What is the condition of things here? You have poured, say positive electricity on to the upper sheet of metal. It acts inductively across the glass upon the under sheet, the positive fluid of which escapes to the earth, leaving the negative behind. You see before your mind's eye two layers holding each other in bondage. Now take hold of your loops and lift the glass plate, so as to separate the upper tin-foil from the lower. What would you expect to occur? Freed from the grasp of the lower layer, the electricity of the upper one will diffuse itself over the electroscope so promptly and powerfully, that if you are not careful you will destroy the instrument by the mutual repulsion of its leaves.

Practise this experiment, which is a very old one of mine, by lowering and lifting the glass plate, and observing the corresponding rhythmic action of the leaves of the electroscope.

Common tin-plate may be used in this experiment instead of tin-foil, and a sheet of vulcanized india-rubber instead of the pane of glass. Or simpler still, for the tin-foil a sheet of common unwarmed foolscap may be employed. Satisfy yourself of this. Spread a *sheet* of foolscap on a table; lay the plate of glass upon it, and spread a *leaf* of foolscap, less than the glass in size, on the plate of glass. Connect the leaf with the electroscope, and charge it, exactly as you charged the tin-foil. On lifting the glass with its leaf of foolscap, the leaves of the electroscope instantly fly apart; on lowering the glass they again fall together. Abandon the under sheet altogether, and make the table the outer coating; if it be not of very dry wood, or covered by an insulating varnish, you will obtain with it the results obtained with the tin-foil, tin, and foolscap. Thus by the simplest means we illustrate great principles.

The withdrawal of the electricity from the electroscope, by lowering the plate of glass, so as to bring the electricity of the upper coating within the grasp of the

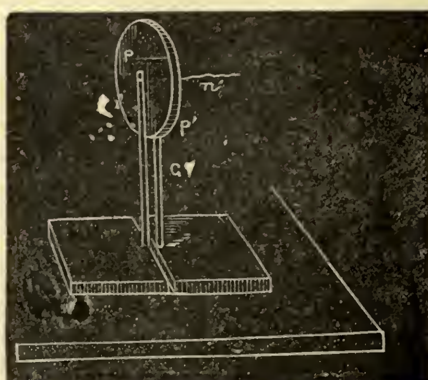


Fig. 41.

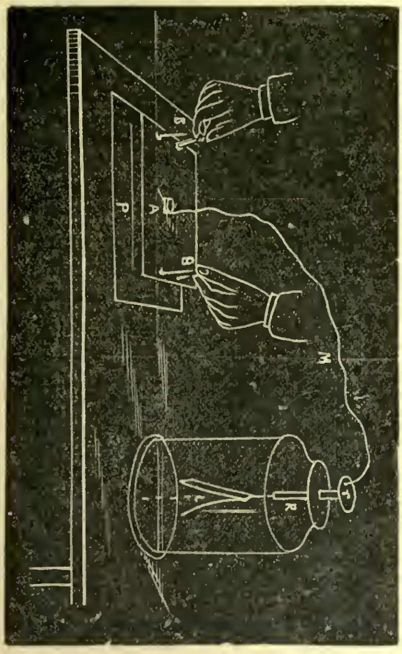


Fig. 42.

lower one, is sometimes called "condensation." The electricity on one plate or sheet was figured as squeezed together, of condensed, by the attraction of the other. A special instrument called a *condenser* is constructed by instrument makers to illustrate the action here explained.

You may readily make a condenser for yourself. Take two circles, P P′, fig. 41, of tin or of sheet zinc, and support the one, P′, by a stick of sealing-wax or glass, G: the other, P, by a metal stem, connected with the earth. The insulated plate, P′, is called the collecting plate; the uninsulated one, P′, the condensing plate. Connect the collecting plate with your electroscope by the wire *w*, and bring the condensing plate near it, leaving, however, a thin space of air between them. Charge the collector, P′, or the wire, *w*, with your glass rod, until the leaves of the electroscope *begin* to diverge. Withdraw the condensing plate, the leaves fly asunder; bring the condensing plate near, the leaves again collapse.

Or vary your construction, and make your condenser thus. Employing the table, or a sheet of foolscap if the table be an insulator, as one plate of the condenser, spread upon it the sheet of india-rubber, P, fig. 42, and lay upon the rubber the sheet of block-tin, A B. Connect the tin by the wire, *w*, with the electroscope, T. Impart electricity to the little weight, A, till the leaves, L, begin to diverge; then lift the tin plate by its two silk loops; the leaves at once fly asunder.

Finally, show your complete knowledge of the Leyden jar, and your freedom from the routine of the instrument-makers by making a "jar" in the following novel way. Stand upon a board supported by warm tumblers. Hold in your right hand a sheet of vulcanized india-rubber, and clasp, with it between you, the left hand of a friend in connection with the earth. Place your left hand on the conductor of the machine, and let it be worked. You and your friend soon feel a crackling and a tickling of the hands, due to the heightening attraction of the opposite electricities across the india-rubber. The "hand-jar" is then charged. To discharge it you have only to bring your other hands together: the shock of the Leyden jar is then felt and its spark seen and heard.

By the discharge of the hand-jar you can fire gunpowder. But this will be referred to more particularly further on. (See § 25.)

§ 23. *Seat of Charge in the Leyden Jar.*

Franklin sought to determine how the charge was hidden in the Leyden jar. He charged with electricity a bottle half filled with water and coated on the outside with tin-foil; dipping the finger of one hand into the water, and touching the outside coating with the other, he received a shock. He was thus led to inquire, Is the electricity in the water? He poured the water into a second bottle, examined it, and found that it had carried no electricity along with it.

His conclusion was "that the electric fire must either have been lost in the decanting, or must have remained in the bottle. The latter he found to be true; for, filling the charged bottle with fresh water, he obtained the shock, and was therefore satisfied that the power of giving it resided in the glass itself." *

* Priestley's "History of Electricity," 3d edition, p. 149.

(An account of Franklin's discoveries was given by him in a series of letters addressed to Peter Collinson, Esq., F.R.S., from 1747 to 1754).

So much for history; but you are to verify the history by repeating Franklin's experiments. Place water in a wide glass vessel; place a second glass vessel within the first, and fill it to the same height with water. Connect the outer water by a wire with the earth, and the inner water by a wire with the electric machine. One or two turns furnish a sufficient charge. Removing the inner wire and dipping one finger into the outside and the other into the inside water, a smart shock is felt. This was Franklin's first experiment.

Pass on to the second. Coat a glass jar with tin-foil (not too high); fill it to the same height with water, and place it on india-rubber cloth. Charge it by connecting the outside coating with the earth, and the water inside (by means of a stem cemented to the bottom of the jar and ending above in a knob) with an electric machine. You obtain a bright spark on discharging. This proves your apparatus to be in good order.

Recharge. Take hold of the charged jar with the india-rubber, and pour the water into a second similar jar. No sensible charge is imparted to the latter. Pour fresh unelectrified water into the first jar, and discharge it. The retention of the charge is shown by a brilliant spark. Be careful in these experiments, or you will fail, as I did at first. The edge of the jar out of which the water is poured has to be surrounded by a band of bibulous paper to catch the final drop, which, trickling down, would discharge the jar.

Experiments like those of Franklin are now made by rendering the coatings of the Leyden jar movable. Such a jar being charged, the interior coating may be lifted out and proved unelectric. The glass may then be removed from the outer coating and the latter proved unelectric. Restoring the jar and coatings, on connecting the two latter, the discharge passes in a brilliant spark.

Make a jar with movable coatings thus: Roll cartridge paper round a good flint-glass tumbler, G, fig 43, to within about an inch of the top. Paste down the lower edge of the paper, and put a paper bottom to it corresponding to the bottom of the glass. Coat the paper, T, inside and out with tin-foil. Make a similar coating, T, for the inside of the tumbler, attaching to it an upright wire,

Fig, 43.

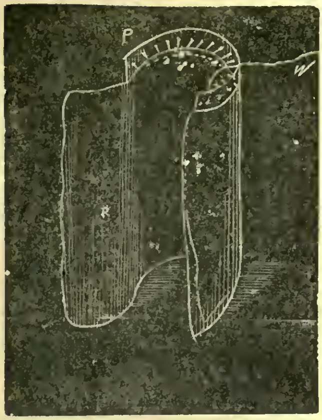
w, ending in a hook. You have then to all intents and purposes a Leyden jar.

Put the pieces together and charge the jar. By means of a rod of glass, sealing-wax, or gutta-percha, lift out the interior coating. It will carry a little electricity away with it. Place it upon a table and discharge it wholly. Then by the hand lift the glass out of the outer coating. Neither of the coatings now shows the slightest symptom of electricity. Restore the tumbler to its outer coating, and by means of the hook and insulating rod, restore the inner coating to its place. Discharge the jar: you obtain a brilliant spark. The electricity which produces this spark must have been resident in and on the glass.

Here, as in all other cases, you can charge your jar with a rubbed glass tube, though a machine in good working order will do it more rapidly. With "Cottrell's rubber," described in the next section, you may greatly exalt the performance of your glass tube.

§ 24. *Ignition by the Electric Spark.—Cottrell's Rubber.—The Tube-machine.*

Various attempts had been vainly made by Nollet and others to ignite inflam-



Fig, 44.

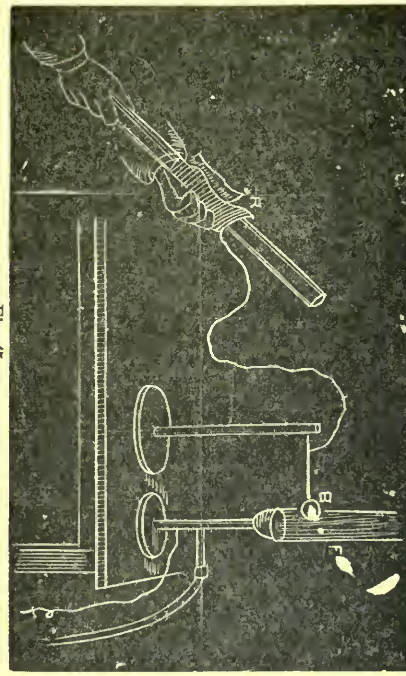


Fig. 45.

mable substances by the electric spark. This was first effected by Ludolf, at the opening of the Academy of Sciences by Frederick the Great at Berlin, on the 23d of January, 1744. With a spark from the sword of one of the court cavaliers present on the occasion, Ludolf ignited sulphuric ether.

Dr. Watson also made numerous experiments on the ignition of bodies by the electric spark. He fired gunpowder and discharged guns. Causing, moreover, a spoon containing ether to be held by an electrified person, he ignited the ether by the finger of an unelectrified person. He also noticed that the spark varied in color when the substances between which it passed varied.

These, and numerous other experiments may be made with a far simpler "machine" than any hitherto described. It was devised for your benefit by Mr. Cottrell. In the electric machine, as we have learned, the prime conductor is flooded with positive electricity through the discharge of the negative from the points against the excited glass. Your glass tube and rubber may be similarly turned to account. A strip of sheet-brass or copper, P, fig. 44, is sewn on to the edge of the silk pad, R, employed as a rubber. Through apertures in the strip about twenty pin-points are introduced, and soldered to the metal. When the tube is clasped by the rubber, the metal strip and points quite encircle the tube.

When a fine wire, *w*, connects the strip of metal with the knob of a Leyden jar, by every downward stroke of the rubber the glass tube is powerfully excited, and hotly following the exciting rubber is the circle of points. From these, against the rod, negative electricity is discharged, the free positive electricity escaping along the wire to the jar, which is thus rapidly charged.

The ignition of gas is readily effected by Cottrell's rubber. Connecting the strip of metal, R, fig. 45, with an insulated metallic knob, B, placed within a quarter or an eighth of an inch of an uninsulated argand burner connected with the earth, at every downward stroke of the rubber a stream of sparks passes between the knob and burner. If gas be turned on, it is immediately ignited by the stream of sparks. Blowing out the flame and repeating the experiment, every stroke of the rubber infallibly ignites the gas.

Sulphuric ether, in a spoon which has been previously warmed, is thus ignited; but the ether soon cools by evaporation; its vapor is diminished by the cold, and it is then less easy to ignite. Bisulphide of carbon may be substituted for the ether, with the certainty that every stroke of the rubber will set it ablaze. The spark thus obtained also fires a mixture of oxygen and hydrogen. The two gases

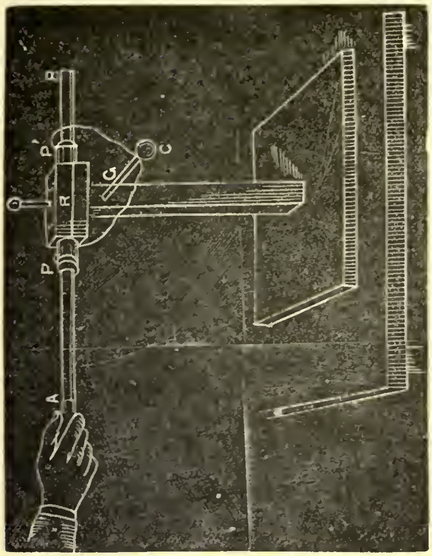


Fig. 46.

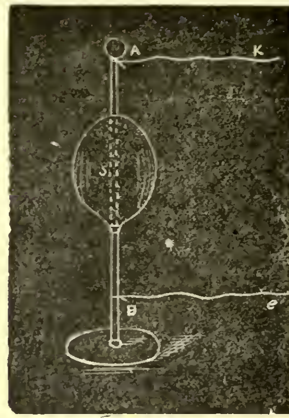


Fig. 47.

unite with explosion to form water, when an electric spark is passed through them.

Mr. Cottrell has also mounted his glass tube so as to render friction in both directions available. The *tube machine* is represented in fig. 46. A B is the glass tube, clasped by the rubber, R. P P′ are two strips of metal furnished with rows of points. From P P′ wires proceed to the knob C, which is insulated by the horizontal stem, G. This insulating stem may be abolished with advantage, the wires from P and P′ being rendered strong enough to support the ball C. At C sparks may be taken, a Leyden jar charged, the electric mill turned, while wires carried from it may be employed in experiments on ignition. I however strongly recommend to your attention the more simple rubber shown in fig. 44.

"Seldom," says Riess, "has an experiment done so much to develop the science to which it belongs as this of the ignition of bodies by the electric sparks." It aroused universal interest; and was repeated in all Royal houses. Money was ready for the further prosecution of electrical research. The experiment afterward spread among the people. Riess considers it probable that the general interest thus excited led to the discovery of the Leyden jar, which was made soon afterward.

Klingenstierna astonished King Frederick of Sweden by igniting a spoon of alcohol with a piece of ice. With Cottrell's rubber and bisulphide of carbon this striking experiment is easily made, and you ought to render your knowledge complete by repeating it. At every stroke of the rubber the spark from the end of a pointed rod of ice infallibly sets the bisulphide on fire.

Cadogan Morgan, in 1785, sought to produce the electric spark in the interior of solid bodies. He inserted two wires into wood, and caused the spark to pass between them: the wood was illuminated with blood-red light, or with yellow light, according as the depth at which the spark was produced was greater or less. The spark of the Leyden jar produced within an ivory ball, an orange, an apple, or under the thumb, illuminates these bodies throughout. A lemon is especially suited to this

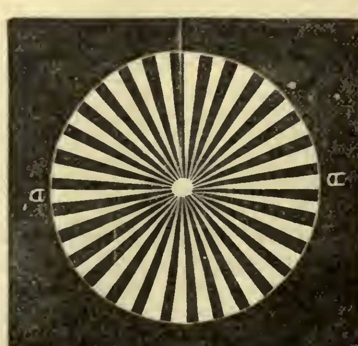


Fig. 48.

experiment, flashing forth at every spark as a spheroid of brilliant golden light. The manner in which the lemon is mounted on the brass stem B is shown in fig. 47. The spark occurs at *s*, in the interval between the stems A and B. A row of eggs in a glass cylinder is also brilliantly illuminated, at the passage of every spark from a Leyden jar.

§ 25. *Duration of the Electric Spark.*

The duration of the electric spark is very brief; in a special case Sir Charles Wheatstone found it to be $\frac{1}{24000}$th of a second. This, however, was the maximum duration. In other cases it was less than the millionth of a second.

When a body is illuminated for an instant, the image of the body remains upon the retina of the eye for about one-fifth of a second. If, then, a body in swift motion be illuminated by an *instantaneous* flash, it will be seen to stand motionless for one-fifth of a second at the point where the flash falls upon it. A rifle bullet passing through the air, and illuminated by an electric flash, would be seen thus motionless; a circle like D D′, fig. 48, divided into black and white sectors, and rotating so quickly as to cause the sectors to blend to a uniform gray, appears, when illuminated by the spark of a Leyden jar, perfectly motionless, with all its sectors revealed. A falling jet of water, which appears continuous, is resolved by the electric flash into its constituent drops. Lightning, as shown by Professor Dove, is similarly rapid in its discharge.

For a long time it was found almost impossible to ignite gunpowder by the electric spark. Its duration is so brief that the powder, when the discharge occurred in its midst, was simply scattered violently about. In 1787 Wolff introduced into the circuit through which the discharge passed a glass tube wetted on the inside. He thereby rendered the ignition certain. This was owing to the retardation of the spark by the imperfect conductor. Gun-cotton, phosphorus, and amadou, which are torn asunder by the unretarded sparks are ignited when the discharge is retarded by a tube of water. A wetted string is the usual means resorted to for retardation when gunpowder is to be discharged.

The instrument usually employed for the ignition of powder is the universal discharger. We make our own discharger thus: I and I′ (fig, 49) are insulating rods of glass or sealing-wax, supporting two metal arms, the ends of which can be brought down upon the little central table s. One of the metal arms of the discharger being connected by a wire *e* with the earth, the separated ends of the two arms are surrounded with powder s. Sending through it the unretarded charge, the powder is scat-

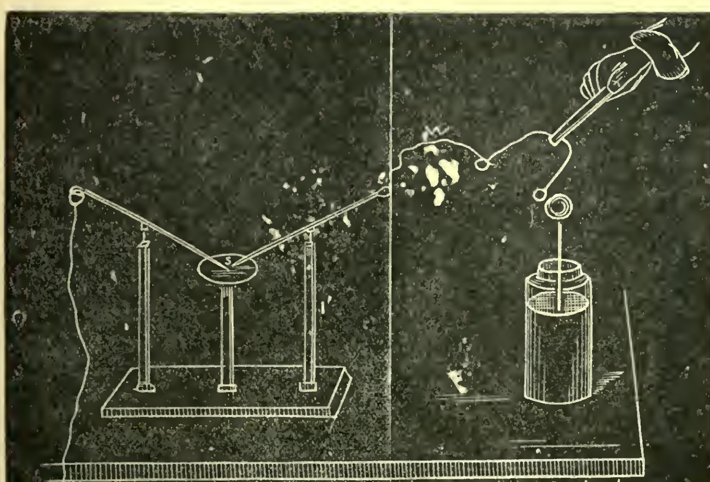


Fig. 49.

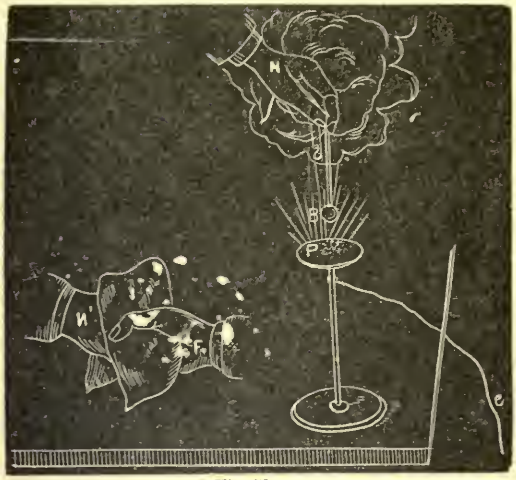


Fig. 50.

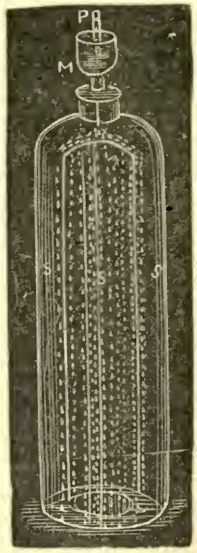


Fig. 51.

tered mechanically. Introducing the wet string *w* into the circuit, ignition infallibly occurs when the spark passes.

This is the place to fulfil our promise to ignite gunpowder by the "hand-jar." Fig. 50 explains the arrangement. N N′ are the hands of the insulated person. F the hand of the uninsulated friend, I the india-rubber between both hands. The lead ball B is suspended by a wet string s. On the little stand P, connected with the earth, is placed the powder. The charging of the hand-jar is described in § 22. When charged, it is only necessary to bring the ball B down upon the powder to cause it to explode.

§ 26. *Electric Light in Vacuo.*

The electric light in vacuo was first observed by Picard in 1675. While carrying a barometer from the Observatory to the Porte St. Michel in Paris, he saw light in the upper portion of the tube. Sebastien and Cassini observed it afterwards in other barometers. John Bernouilli devised a "mercurial phosphorus," by shaking mercury in a tube which had been exhausted by an air-pump. This was handed to the King of Prussia—Frederick I.—who awarded for it a medal of forty ducats value. The great mathematician wrote a poem in honor of the occasion.

Bernouilli failed to explain the effect. The explanation was reserved for Hauksbee, who in 1705 took up the subject and experimented upon it before the Royal Society. On the plate of an air-pump he placed two bell-jars, one over the other. The outer and larger jar was open at the top. Into the opening Hauksbee fixed, air-tight, a funnel, which he stopped with a plug of wood and filled with mercury. He exhausted the space between the two jars, withdrew the wooden plug and allowed the mercury to stream against the outer surface of the inner jar. He thus obtained a shower of fire. This is a truly beautiful experiment when witnessed by an observer close at hand.

A copy of Hauksbee's own figure illustrating this experiment is annexed, fig. 51. M is the funnel containing the mercury, P the plug of wood, S the outer and S the inner bell-jar. Instead of the plug P, an india-rubber tube, held by a clip, may be employed with advantage to connect the funnel with the exhausted jar. By gradually relaxing the clip the mercury may be made to fall at a rate corresponding to the maximum luminous effect. The streams of light produced are very beautiful, but they are more continuous than they are shown to be by Hauksbee.

In 1706 Hauksbee referred the phe-

nomenon to its true cause, namely, the friction between mercury and glass in the highly rarefied air. John Bernouilli ridiculed Hauksbee's explanation. But truth outlives ridicule, and it is now universally admitted that Hauksbee was right.

Hauksbee also made the following experiment, which, as shown by Riess, is explained by reference to the principle of induction. A hollow glass globe was mounted so as to be capable of quick rotation. It was exhausted, and while it rotated the hand was placed against it in the dark. It was positively electrified by the hand. This positive electricity acted inductively on the glass itself, attracting its negative, but discharging its positive as a luminous glow through the rarefied air within. Hauksbee was able to read by the light thus produced.

By such experiments it was shown that rarefied air favored the passage of electricity. Dry air is in fact an insulator, which must be broken through to produce the electric spark. Through an exhausted glass tube six feet long a discharge freely passes which would be incompetent to leap over the fiftieth part of this interval in air. But whereas the spark in air is dense and brilliant, the discharge in vacuo fills the exhausted tube with a diffuse light.

(It is here worthy of remark that at a very early period Grummert, a Pole, proposed the employment of this diffuse electric light to illuminate coal mines—a notion which has been revived in our day. The light in this form is not competent to ignite the explosive gases which produce such terrible disasters in mines.)

Priestley, in his "History of Electricity," thus describes the light in vacuo. "Take a tall receiver, very dry, and in the top of it insert with cement a wire not very acutely pointed, then exhaust the receiver and present the knob of the wire to the conductor, and every spark will pass through the vacuum in a broad stream of light, visible through the whole length of the receiver, be it ever so tall. This stream often divides itself into a variety of beautiful rivulets, which are continually changing their course, uniting and dividing again in the most pleasing manner. If a jar be discharged through this vacuum, it gives the appearance of a very dense body of fire, darting directly through the centre of the vacuum without ever touching the sides."

Cavendish employed a double barometer-tube, bent into the form of a horseshoe with its curved portion empty to show the passage of electricity through a vacuum. It is really not the vacuum which conducts the electricity, but the highly attenuated air and vapor which fill the space above the barometric columns. When the mercury employed is carefully purged of air and moisture by previous boiling, the space above the mercury, as proved by Walsh, De Luc, Morgan, and Davy, is wholly incapable of conducting electricity. Similar experiments have been made in the laboratory of Mr. Gassiot, to whom we are indebted for so many beautiful electrical experiments. Professor Dewar has also brought his experimental skill to bear with success upon this subject.

Electricity, therefore, does not pass through a true vacuum; it requires ponderable matter to carry it. If a gold-leaf electroscope be kept at a distance from all conductors, it may be kept charged for an almost indefinite period in a good air-pump vacuum.

The matter rendered thus luminous by the electrical discharge is attracted and repelled like other electrified matter. "A finger," says Priestley, "put on the outside of the glass will draw it [the luminous stream] wherever a person pleases. If the vessel be grasped with both hands, every spark is felt like the pulsation of a great artery, and all the fire makes towards the hands. This pulsation is felt at some distance from the receiver; and in the dark a light is seen betwixt the hands and glass."

"All this," continues the historian of electricity, "while the pointed wire is supposed to be electrified positively; if it be electrified negatively the appearance is remarkably different. Instead of streams of fire, nothing is seen but one uniform luminous appearance, like a white cloud, or the milky-way on a clear starlight night. It seldom reaches the whole length of the vessel, but is generally only like a lucid ball at the end of the wire."

Of the two appearances here described

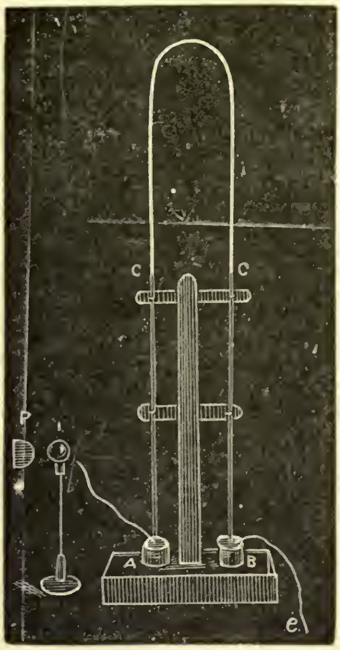


Fig. 52.

the former is now known as the *electric brush*, and the latter as the *electric glow*. Both can be produced in unconfined air. The glow is sometimes seen on the masts of ships, and it is mentioned by the ancients as appearing on the points of lances. It is called St. Ermo's or St. Elmo's fire, after the sailors' saint, Erasmus, who suffered martyrdom at Gaeta, at the beginning of the fourth century.

The purple color of the diffused light in attenuated air was noticed by Hauksbee. The color depends upon the residue of attenuated gas, or vapor, through which the discharge passes. If it be an oxygen-residue the light is whitish, if it be a hydrogen-residue the light is red, if a nitrogen-residue the light is purple exactly resembling that displayed at times by the aurora borealis—a color doubtless due to the discharge of electricity through the attenuated nitrogen of the air

Electric light in vacuo is readily produced by the friction of an amalgamated rubber against the outside of an exhausted tube. The light is also produced by the friction of mercury within a barometric vacuum. The discharges through tubes many feet in length and exhausted by an air-pump are very fine. The double barometer tube of Cavendish also yields a truly splendid bow of light when a strong electric discharge is sent through it. For this experiment fig. 52 shows the best arrangement. P is the prime conductor of an electrical machine, I an insulated metal ball, connected by a wire with the mercury trough A. The trough B is connected by a wire with the earth. C and C′ mark the height of the mercurial columns. When the machine is worked sparks pass from P to I, a vivid bow of light at each passage stretching from C to C′. By causing I to apporach P, the discharges become more frequent, but more feeble; by augmenting the distance P I, the sparks become rarer, but more strong. When very strong, a bow of dazzling brilliancy accompanies every spark.*

Small tubes for these experiments are best obtained from philosophical instrument-makers.

§ 27. *Lichtenberg's Figures.*

Lichtenberg devised a means of revealing the condition of an electrified surface by dusting it with powder. Red lead in passing through muslin is positively electrified; flower of sulphur is negatively electrified. Whisking a fox's brush over a cake of resin, and drawing over the surface the knob of a Leyden jar, positively charged, the resin is rendered in part negative and in part positive. Dusting the mixed powder over the surface, the sulphur arranges itself over the positive places, and the red lead over the negative places, a very beautiful pattern being the result.

This experiment of Lichtenberg's constituted the germ of Chladni's important acoustical researches. "Chladni's figures" were the direct offspring of "Lichtenberg's figures."

§ 28. *Surface Compared with Mass. Distribution of Electricity in Hollow Conductors.*

Monnier proved that the charge of a

* It is well to have the interval P I at some distance from the bow, so that the light of the spark shall not impair the effect of the discharge upon the eye.

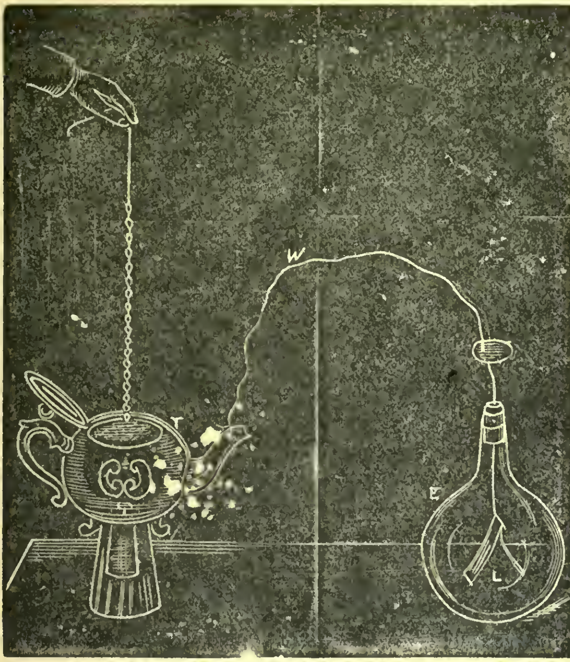


Fig. 53.

conductor depended upon its surface, and not upon its solid contents. An anvil weighing 200 pounds gave a smaller spark than a speaking trumpet weighing 10 pounds. A solid ball of lead gave a spark only of the same force as that obtained from a piece of thin lead of the same superficies, bent into the form of a hoop. Finally Monnier obtained a strong spark from a long strip of sheet lead, but a very small one when it was rolled into a lump.

Le Roi and D'Arcy showed that a hollow sphere accepted the same charge when empty as when filled with mercury, which augmented its weight sixty-fold. And this proves the influence of *surface* as distinguished from *mass*.

The distribution of electricity is well illustrated by the deportment of hollow bodies. Impart by your carrier (fig. 15) successive measures of electricity to the interior of an insulated ice-pail, or a pewter pot. On testing the interior of the vessel with the carrier and an electroscope no electricity is found there; but it is found on the external surface. A hat suspended by silk strings answers as well as the ice-pail.

This experiment with the hat is a very instructive one. The hat may be charged either with Cottrell's rubber or with your rubbed glass tube.

Notice, when testing, that you take your strongest charges from the edges and not from the round or flat surface of the hat. The strongest charge of all is communicated to the carrier by the leaf of the hat.

The successive charges may be communicated to the hat by a metal ball suspended by silk. The charged ball, on touching the interior surface, becomes completely unelectric.

Franklin placed a long chain in a silver tea-pot which he electrified. Connecting his tea-pot with a pith-ball electroscope he produced a divergence. Then lifting the chain by a silk string he found that over the portion outside the teapot the electricity diffused itself, this withdrawal of the electricity from the electroscope being announced by the partial collapse of the divergent pith-balls.

The mode of repeating this experiment is shown in fig. 53, where T is the teapot, supported on a good glass tumbler G, and connected by the wire *w* with the

electroscope E. The effect is small, but distinct.

The greatest experiment with hollow conductors was made by Faraday, who placed himself in a cubical chamber built of laths and covered with paper and wire gauze. It was suspended by silk ropes. Within this chamber he could not detect the slightest sign of electricity, however delicate his electroscope, and however strongly the sides of the chamber might be electrified.

§ 29. *Physiological Effects of the Electric Discharge.*

The physiological effect of the electric shock has been studied in various ways. Graham caused a number of persons to lay hold of the same metal plate, which was connected with the outer coating of a charged Leyden jar, and also to lay hold of a rod by which the jar was discharged. The shock divided itself equally among them.

The Abbé Nollet formed a line of one hundred and eighty guardsmen, and sent the discharge through them all. He also killed sparrows and fishes by the shock. The analogy of these effects with those produced by thunder and lightning could not escape attention, nor fail to stimulate inquiry.

Indeed, as experimental knowledge increased, men's thoughts became more definite and exact as regards the relation of electrical effects to thunder and lightning. The Abbé Nollet thus quaintly expresses himself: "If any one should take upon him to prove, from a well-connected comparison of phenomena, that thunder is, in the hands of Nature, what electricity is in ours, and that the wonders which we now exhibit at our pleasure are little imitations of those great effects which frighten us; I avow that this idea, if it was well supported, would give me a great deal of pleasure." He then points out the analogies between both, and continues thus: "All those points of analogy, which I have been some time meditating, begin to make me believe that one might, by taking electricity as the model, form to one's self in relation to thunder and lightning, more perfect and more probable ideas than what have been offered hitherto."*

* Priestley's "History of Electricity," pp. 151–52.

These views were prevalent at the time now referred to, and out of them grew the experimental proof by the great physical philosopher, Franklin, of the substantial identity of the lightning flash and the electric spark.

Franklin was twice struck senseless by the electric shock. He afterwards sent the discharge of two large jars through six robust men; they fell to the ground and got up again without knowing what had happened; they neither heard nor felt the discharge. Priestley, who made many valuable contributions to electricity, received the charge of two jars, but did not find it painful.

This experience agrees with mine. Some time ago I stood in this room with a charged battery of fifteen large Leyden jars beside me. Through some awkwardness on my part I touched the wire leading from the battery, and the discharge went through me. For a sensible interval life was absolutely blotted out, but there was no trace of pain. After a little time consciousness returned; I saw confusedly both the audience and the apparatus, and concluded from this, and from my own condition, that I had received the discharge. To prevent the audience from being alarmed, I made the remark that it had often been my desire to receive such a shock accidentally, and that my wish had at length been fulfilled. But though the *intellectual* consciousness of my position returned with exceeding rapidity, it was not so with the *optical* consciousness. For, while making the foregoing remark, my body presented to my eyes the appearance of a number of separate pieces. The arms, for example, were detached from the trunk and suspended in the air. In fact, memory and the power of reasoning appeared to be complete, long before the restoration of the optic nerve to healthy action.

This may be regarded as an experimental proof that people killed by lightning suffer no pain.

§ 30. *Atmospheric Electricity.*

The air at all times can be proved to be a reservoir of electricity, which undergoes periodic variation. We have seen that ingenious men began soon to suspect a common origin for the crack-

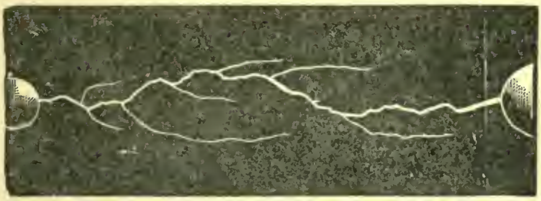


Fig. 54.

ling and light of the electric spark, and thunder and lightning. The greatest investigator in this field is the celebrated Dr. Franklin. He made an exhaustive comparison of the effects of electricity and those of lightning. The lightning flash he saw was of the same shape as the elongated electric spark ; like electricity, lightning strikes pointed objects in preference to others ; lightning pursues the path of least resistance ; it burns, dissolves metals, rends bodies asunder, and strikes men blind. Franklin imitated all these effects, striking a pigeon blind, and killing a hen and turkey by the electrical discharge. I place before you in fig. 54 with a view to its comparison with a discharge of forked lightning, the long spark obtained from an effective ebonite machine, furnished with a conductor of a special construction, which favors length of spark.

Having completely satisfied his mind by this comparison of the identity of both agents, Franklin proposed to draw electricity from the clouds by a pointed rod erected on a high tower. But before the tower could be built he succeeded in his object by means of a kite with a pointed wire attached to it. The electricity descended by the hempen string which held the kite, to a key at the end of it, the key being separated from the observer by a silken string held in the hand. Franklin thus obtained sparks, and charged a Leyden phial with atmospheric electricity.

But, spurred by Franklin's researches, an observer in France had previously proved the electrical character of lightning. A translation of Franklin's writings on the subject fell into the hands of the naturalist Buffon, who requested his friend D'Alibard to revise the translation. D'Alibard was thus induced to erect an iron rod 40 feet long, supported by silk strings, and ending in a sentry-box. It was watched by an old dragoon named Coiffier, who on the 10th of May, 1752, heard a clap of thunder, and immediately afterwards drew sparks from the end of the irod rod.

The danger of experiments with metal rods was soon illustrated. Professor Richmann of St. Petersburg had a rod raised three or four feet above the tiles of his house. It was connected by a chain with another rod in his room ; the latter rod resting in a glass vessel, and being therefore insulated from the earth. On the 6th of August, 1753, a thunder cloud discharged itself against the external rod ; the electricity passed downwards along the chain ; on reaching the rod below, it was stopped by the glass vessel, darted to Richmann's head, which was about a foot distant, and killed him on the spot. Had a perfect communication existed between the lower rod and the earth, the lightning in this case would have expended itself harmlessly.

In 1749 Franklin proposed lightning conductors. He repeated his recommendation in 1753. He was opposed on two grounds. The Abbé Nollet, and those who thought with him, considered it as impious to ward off heaven's lightnings, as for a child to ward off the chastening of its father. Others thought that the conductors would "invite," the lightning to break upon them. A long discussion was also carried on as to whether the conductors should be blunt or pointed. Wilson advocated blunt conductors against Franklin, Cavendish, and Watson. He so influenced George III., hinting that the points were a republican device to injure his Majesty, that the pointed conductors on Buckingham House were changed for others ending in balls. Experience of the most varied kind has justified the employment of pointed conductors. In 1769 St. Paul's Cathedral was first protected.

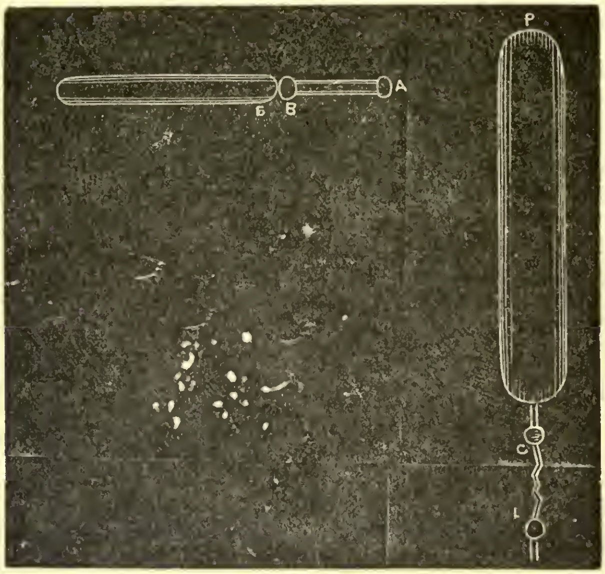


Fig. 55.

The most decisive evidence in favor of conductors was obtained from ships; and such evidence was needed to overcome the obstinate prejudice of seamen. Case after case occurred in which ships unprotected by conductors were singled out from protected ships, and shattered or destroyed by lightning. The conductors were at first made movable, being hoisted on the approach of a thunderstorm; but these were finally abandoned for the fixed lightning conductors devised by the late Sir Snow Harris. The saving of property and life by this obvious outgrowth of electrical research is incalculable.

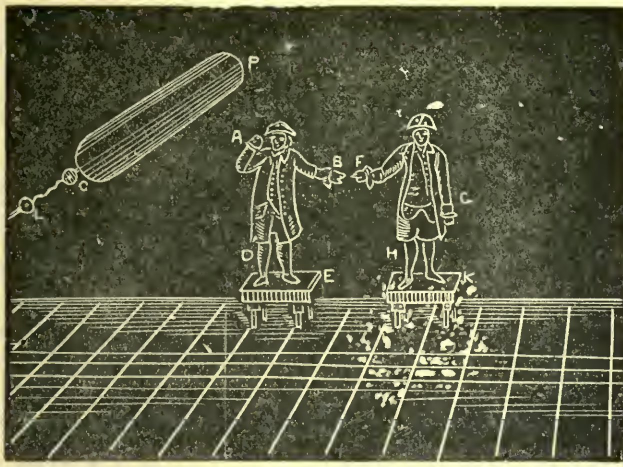
§ 31. *The Returning Stroke.*

In the year 1779 Charles, Viscount Mahon, afterwards Earl Stanhope, published his "Principles of Electricity." On the title-page of the book stands the following remark:—"This treatise comprehends an explanation of an electrical *returning stroke*, by which fatal effects may be produced even at a vast distance from the place where the lightning falls."

Lord Mahon's experiments, which are models of scientific clearness and precision, will be readily understood by reference to the principles of electric induction, with which you are now so familiar. It need only be noted here that whenever he speaks of a body being plunged in an "electrical atmosphere," he means that the body is exposed to the inductive action of a second electrified body, which latter he supposed to be surrounded by such an atmosphere.

A few extracts from his work will give a clear notion of the nature of his discovery:

"I placed an insulated metallic cylinder, A B, fig. 55, within the electrical atmosphere of the prime conductor [P C] when charged, but beyond the striking distance. The distance between the near end A of the insulated metallic body and the side of the prime conductor was 20 inches. The body A B was of brass, of a cylindrical form, 18 inches long, by two inches in diameter. I then placed another insulated brass body E F, 40 inches long by about 3¾ inches in diameter, with its end E at the distance of about one-tenth of an inch from the end B of the other metallic body A B. I electrified the prime conductor. All the time that it was receiving its *plus* charge of electricity there passed a great number of weak (red or



Fig, 56.

purple) sparks from the end B of the near body A B into the end E of the remote body E F."

Make clear to your mind the origin of this stream of weak red or purple sparks. It is obviously due to the inductive action of the prime conductor P C upon the body A B. The positive electricity of A B being repelled by the prime conductor, passed as a stream of sparks to E F.

"When the prime conductor, having received its full charge, came suddenly to discharge, with an explosion, its superabundant electricity on a large brass ball L, which was made to communicate with the earth, it always happened that the electrical fluid, which had been gradually expelled from the body A B and driven into the body E F, did suddenly return from the body E F into the body A B, in a strong and bright spark, at the very instant that the explosion took place upon the ball L.

"This I call the electrical *returning stroke.*"

For the two conductors Lord Mahon then substituted his own body and that of another person, both of them standing upon insulating stools. He continues thus :

"I placed myself upon an insulating stool E (fig. 56), so as to have my right arm A at the distance of about 20 inches from a large prime conductor : another person, standing upon another insulating stool K, brought his right hand F within one quarter of an inch of my left hand B.

"When the prime conductor began to receive its plus charge of electricity, we felt the electrical fluid running out of my hand B into his hand F.

"When we separated our hands B and F a little, the electricity passed between us in small sparks, which sparks increased in sharpness the farther we removed our hands B and F asunder, until we had brought them quite out of a striking distance. The intervals of time between these *departing sparks* increased also the more the distance between our hands B and F was increased, as must necessarily be the case.

"As soon as the prime conductor came suddenly to discharge its electricity upon the ball L, the superabundant electricity which the other person had received from my body did then return from him to me in a sharp spark, which issued from his hand F at the very instant that the explosion of the prime conductor took place upon the ball L.

"I still continued upon the insulating stool E, and I desired the other person to stand upon the floor. The returning stroke between us was *still stronger* than it had yet been. The reason of it was this : The other person being no longer insulated, transmitted his superabundant electricity freely into the earth. I consequently became still more negative than before.

"Now, when the returning stroke

came to take place, not only the electricity which had passed from my body into the body of the other person, but also the electricity which had passed from my body into the earth (through the other person) did suddenly return upon me from his hand F to my hand B, at the same instant that the discharge of the prime conductor took place upon the ball L. This caused the returning stroke to be stronger than before."

Lord Mahon fused metals, and produced strong physiological effects by the return stroke.

In nature disastrous effects may be produced by the return stroke. The earth's surface, and animals or men upon it, may be powerfully influenced by one end of an electrified cloud. Discharge may occur at the other end, possibly miles away. The restoration of the electric equilibrium by the return shock may be so violent as to cause death.

This was clearly seen and illustrated by Lord Mahon. Fig. 57 is a reduced copy of his illustration. A B C is the electrified cloud, the two ends of which, A and C, come near the earth. The discharge occurs at C. A man at F is killed by the returning stroke, while the people at D, nearer to the place of discharge, but farther from the cloud are uninjured.

With the view of still further testing your knowledge of induction, I have here copied a portion of this admirable essay; but the entire memoir of Lord Mahon would constitute a most useful and interesting lesson in eléctricity.

For our own instruction we can illustrate the return shock thus:—Connect one arm of your universal discharger, fig. 49, with a conductor like C, fig. 20 and the other arm with the earth. Bring C within a few inches of your prime conductor, but not within striking distance; on working the machine a stream of feeble sparks will pass from point to point of the discharger. Let the prime conductor be discharged from time to time by an assistant; at every discharge the returning stroke is announced by a flash between the points of the discharger at *s*. If gun-cotton with a little fulminating powder scattered on it, or a fine silver wire be introduced between the points of the discharger, the one is exploded and the other deflagrated.

The stream of repelled sparks first seen may be entirely abolished by establishing an *imperfect* connection between the conductor C and the earth; a chain resting upon the dry table on which the conductor stands will do. The chain permits the feebler sparks to pass through it in

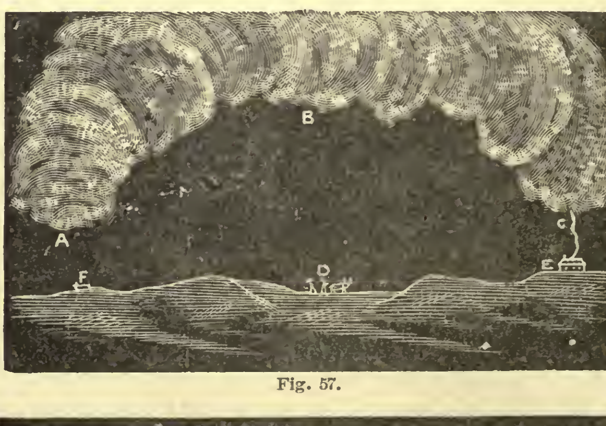


Fig. 57.

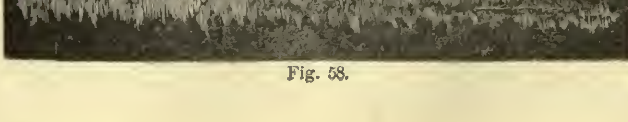


Fig. 58.

preference to crossing the space s; but the returning stroke is too strong and sudden to find a sufficiently open channel through the table and chain, and on the discharge of the prime conductor the spark is seen.

It was the action of the return shock upon a dead frog's limbs, observed in the laboratory of Professor Galvani, that led to Galvani's experiments on animal electricity; and led further to the discovery, by Volta, of the electricity which bears his name.

§ 32. *The Leyden Battery, its Currents, and some of their Effects.*

In the ordinary Leyden battery described in § 19 all the inner coatings are connected together, and all the outer coatings are also connected together. Such a battery acts as a single large jar of extraordinary dimensions.

Wires are warmed by a moderate electric discharge; by augmenting the charge they are caused to glow; with a strengthened charge the metal is torn to pieces; fusion follows; and by still stronger charges the wires are reduced to metallic dust and vapor.

For such experiments the wire must be thin. Without resistance we can have no heat, and when the wire is thick we have little resistance. The mechanism of the discharge, as shown by the figures produced, is different in different wires. The figure produced by the dust of a deflagrated silver wire on white paper is shown in fig. 58.

When the discharge of a powerful battery is sent through a long steel chain with the ends of its links unsoldered, the sparks between the unsoldered links carry the incandescent particles of the steel along with them. These are consumed in the air, a momentary blaze occurring along the entire chain. Chain cables have been fused by being made the channels of a flash of lightning.

Retaining our conception of an electric fluid, at this point we naturally add to it the conception of *a current*. It is the electric current which produces the effects just described. In many of our former experiments we had electricity at rest (static electricity), here we have electricity in motion (dynamic electricity).

Sending the current from a battery through a flat spiral (the primary) formed of fifty or sixty feet of copper wire, and placing within a little distance of it a second similar spiral (the secondary) with its ends connected; the passage of the current in the first spiral excites in the second a current, which is competent to deflagrate wires, and to produce all the other effects of the electrical discharge. Even when the spirals are some feet asunder, the shock produced by the secondary current is still manifest.

The current from the secondary spiral may be carried round a third; and this third spiral may be allowed to act upon a fourth, exactly as the primary did upon the secondary. A tertiary current is thus evoked by the secondary in the fourth spiral.

Carrying this tertiary current round a fifth spiral, and causing it to act inductively upon a sixth, we obtain in the latter a current of the fourth order. In this way we generate a long progeny of currents, all of them having the current sent from the battery through the first spiral for a common progenitor. To Prof. Henry of the United States, and to Prof. Riess of Berlin, we are indebted for the investigation of the laws of these currents. These researches, however, were subsequent to, and were indeed suggested by, experiments of a similar character previously made by Faraday with Voltaic electricity.

Besides the electricity of friction and induction we have the following sources and forms of this power.

The contact of dissimilar metals produces electricity.

The contact of metals with liquids produces electricity.

A mere variation of the character of the contact of two bodies produces electricity.

Chemical action produces a continuous flow of electricity (voltaic electricity).

Heat, suitably applied to dissimilar metals, produces a continuous flow of electricity (thermo-electricity).

The heating and cooling of certain crystals produce electricity (pyro-electricity).

The motion of magnets, and of bodies carrying electric currents, produces electricity (magneto-electricity).

The friction of sand against a metal plate produces electricity.

The friction of condensed water-particles against a safety valve, or better still against a box-wood nozzle through which steam is driven, produces electricity (Armstrong's hydro-electric machine).

These are different manifestations of one and the same power; and they are all evoked by an equivalent expenditure of some other power.

Conclusion.

Our experimental researches end here. I would now bespeak your attention for five minutes longer. The expensiveness of apparatus is sometimes urged as an obstacle to the introduction of science into schools. I hope it has been shown that the obstacle is not a real one. Leaving out of account the few larger experiments, which have contributed but little to our knowledge, it is manifest that the wise expenditure of a couple of guineas would enable any competent teacher to place the leading facts and principles of frictional electricity completely at the command of his pupils; giving them thereby precious knowledge, and still more precious intellectual discipline—a discipline which invokes observation, reflection, prevision by the exercise of reason, and experimental verification.

And here, if I might venture to do so, I would urge upon the science teachers of our public and other schools that the immediate future of science as a factor in English education depends mainly upon them. I would respectfully submit to them whether it would not be a mistake to direct their attention at present to the collection of costly apparatus. Their principal function just now is to arouse a love for scientific study. This is best done by the exhibition of the needful facts and principles with the simplest possible appliances, and by bringing their pupils into contact with actual experimental work.

The very time and thought spent in devising such simple instruments will give the teacher himself a grasp and mastery of his subject which he could not otherwise obtain; but it ought to be known by the head masters of our schools that time is needed, not only for devising such instruments, but also for preparing the experiments to be made with them after they have been devised. No science teacher is fit to meet his class without this distinct and special preparation before every lesson. His experiments are part and parcel of his language, and they ought to be as strict in logic, and as free from stammering, as his spoken words. To make them so may imply an expenditure of time which few head masters now contemplate, but it is a necessary expenditure, and they will act wisely in making provision for it.

To them, moreover, in words of friendly warning, I would say, make room for science by your own healthy and spontaneous action, and do not wait until it is forced upon you by revolutionary pressure from without. The condition of things now existing cannot continue. Its simple statement suffices to call down upon it the condemnation of every thoughtful mind. With reference to the report of a Commission appointed last year to inquire into the scientific instruction of this country, Sir John Lubbock writes as follows:—"The Commissioners have published returns from more than a hundred and twenty of the larger endowed schools. In more than half of these no science whatever is taught; only thirteen have a laboratory, and only eighteen possess any scientific apparatus. Out of the whole number, less than twenty schools devote as much as four hours a week to science, and only thirteen attach any weight at all to scientific subjects in the examinations."

Well may the Commissioners pronounce such a state of things to be nothing less than a national calamity! If persisted in, it will assuredly be followed by a reaction which the truest friends of classical culture in England will have the greatest reason to deplore.

APPENDIX.

AN ELEMENTARY LECTURE ON MAGNETISM.*

WE have no reason to believe that the sheep or the dog, or, indeed, any of the lower animals, feel an interest in the laws

* From the author's volume, "Fragments of Science."

by which natural phenomena are regulated. A herd may be terrified by a thunder-storm; birds may go to roost, and cattle return to their stalls during a solar eclipse; but neither birds nor cattle, as far as we know, ever think of inquiring into the causes of these things. It is otherwise with man. The presence of natural objects, the occurrence of natural events, the varied appearances of the universe in which he dwells, penetrate beyond his organs of sense, and appeal to an inner power of which the senses are the mere instruments and excitants. No fact is to him either final or original. He cannot limit himself to the contemplation of it alone, but endeavors to ascertain its position in a series to which the constitution of his mind assures him it must belong. He regards all that he witnesses in the present as the efflux and sequence of something that has gone before, and as the source of a system of events which is to follow. The notion of spontaneity, by which in his ruder state he accounted for natural events, is abandoned; the idea that Nature is an aggregate of independent parts also disappears, as the connection and mutual dependence of physical powers become more and more manifest; until he is finally led, and that chiefly by the science of which I happen this evening to be the exponent, to regard Nature as an organic whole, as a body each of whose members sympathise with the rest, changing, it is true, from ages to ages, but without one real break of continuity, or a single interruption of the fixed relations of cause and effect.

The system of things which we call Nature is, however, too vast and various to be studied first-hand by any single mind. As knowledge extends there is always a tendency to subdivide the field of investigation, its various parts being taken up by different individuals, and thus receiving a greater amount of attention than could possibly be bestowed on them if each investigator aimed at the mastery of the whole. East, west, north, and south, the human mind pushes its conquests; but the centripetal form in which knowledge, as a whole, advances, spreading ever wider on all sides, is due in reality to the exertions of individuals, each of whom directs his efforts, more or less, along a single line. Accepting, in many respects, his culture from his fellow-men, taking it from spoken words and from written books, in some one direction, the student of nature must naturally touch his work. He may otherwise be a distributor of knowledge, but not a creator, and fails to attain that vitality of thought and correctness of judgment which direct and habitual contact with natural truth can alone impart.

One large department of the system of Nature which forms the chief subject of my own studies, and to which it is my duty to call your attention this evening, is that of physics, or natural philosophy. This term is large enough to cover the study of Nature generally, but it is usually restricted to a department which, perhaps, lies closer to our perceptions than any other. It deals with the phenomena and laws of light and heat—with the phenomena and laws of magnetism and electricity—with those of sound—with the pressures and motions of liquids and gases, whether in a state of translation or of undulation. The science of mechanics is a portion of natural philosophy, though at present so large as to need the exclusive attention of him who would cultivate it profoundly. Astronomy is the application of physics to the motions of the heavenly bodies, the vastness of the field causing it, however, to be regarded as a department in itself. In chemistry physical agents play important parts. By heat and light we cause bodies to combine, and by heat and light we decompose them. Electricity tears asunder the locked atoms of compounds, through their power of separating carbonic acid into its constituents; the solar beams build up the whole vegetable world, and by it the animal, while the touch of the self-same beams causes hydrogen and chlorine to unite with sudden explosion and form by their combination a powerful acid. Thus physics and chemistry intermingle, physical agents being employed by the chemist as a means to an end; while in physics proper the laws and phenomena of the agents themselves, both qualitative, and quantitative, are the primary objects of attention.

My duty here to-night is to spend an hour in telling how this subject is to be studied, and how a knowledge of it is to be imparted to others. When first invited to do this, I hesitated before accepting the responsibility. It would be easy to entertain you with an account of what natural philosophy has accomplished. I might point to those applications of science regarding which we hear so much in the newspapers, and which we often find mistaken for science itself. I might, of course, ring changes on the steam-engine and the telegraph, the electrotype and the photograph, the medical application of physics, and the million other inlets by which scientific thought filters into practical life. That would be easy compared with the task of informing you how you are to make the study of physics the instrument of your own culture, how you are to possess its facts and make them living seeds which shall take root and grow in the mind, and not lie like dead lumber in the storehouse of memory. This is a task much heavier than the mere cataloguing of scientific achievements; and it is one which, feeling my own want of time and power to execute it aright, I might well hesitate to accept.

But let me sink excuses, and attack the work to the best of my ability. First and foremost, then, I would advise you to get a knowledge of facts from actual observation. Facts looked at directly are vital; when they pass into words half the sap is taken out of them. You wish, for example, to get a knowledge of magnetism; well, provide yourself with a good book on the subject, if you can, but do not be content with what the book tells you; do not be satisfied with its descriptive wood-cuts; see the actual thing

yourself. Half of our book-writers describe experiments which they never made, and their descriptions often lack both force and truth; but no matter how clever or conscientious they may be, their written words cannot supply the place of actual observation. Every fact has numerous radiations, which are shorn off by the man who describes it. Go, then, to a philosophical instrument-maker, and give, according to your means, for a straight-bar magnet say, half a crown, or, if you can afford it, five shillings for a pair of them; or get a smith to cut a length of ten inches from a bar of steel an inch wide and half an inch thick; file its ends decently, harden it, and get somebody like myself to magnetize it. Two bar-magnets are better than one. Procure some darning-needles such as these. Provide yourself also with a little unspun silk; which will give you a suspending fibre void of torsion; make a little loop of paper or of wire, thus, and attach your fibre to it. Do it neatly. In the loop place your darning-needle, and bring the two ends or poles, as they are called, of your magnet successively up to either end of the needle. Both the poles, you find, attract both ends of the needle. Replace the needle by a bit of annealed iron wire, the same effects ensue. Suspend successively little rods of lead, copper, silver, or brass, of wood, glass, ivory, or whalebone: the magnet produces no sensible effect upon any of these substances. You thence infer a special property in the case of steel and iron. Multiply your experiments, however, and you will find that some other substances besides iron are acted upon by your magnet. A rod of the metal nickel, or of the metal cobalt, from which the blue color used by painters is derived, exhibits powers similar to those observed with the iron and steel.

In studying the character of the force you may, however, confine yourself to iron and steel, which are always at hand. Make your experiments with the darning-needle over and over again; operate on both ends of the needle; try both ends of the magnet. Do not think the work stupid; you are conversing with Nature, and must acquire a certain grace and mastery over her language; and these practice can alone impart. Let every movement be made with care, and avoid slovenliness from the outset. In every one of your experiments endeavor to feel the responsibility of a moral agent. Experiment, as I have said, is the language by which we address Nature, and through which she sends her replies; in the use of this language a lack of straightforwardness is as possible as it is prejudicial. If you wish to become acquainted with the truth of Nature, you must from the first resolve to deal with her sincerely.

Now remove your needle from its loop, and draw it from end to end along one of the ends of the magnet; re-suspend it, and repeat your former experiment. You find the result different. You now find that each extremity of the magnet attracts one end of the needle and repels the other. The simple attraction observed in the first instance is now replaced by a *dual* force. Repeat the experiment till you have thoroughly observed the ends which attract and those which repel each other.

Withdraw the magnet entirely from the vicinity of your needle, and leave the latter freely suspended by its fibre. Shelter it as well as you can from currents of air, and if you have iron buttons on your coat or a steel penknife in your pocket, beware of their action. If you work at night, beware of iron candlesticks, or of brass ones with iron rods inside. Freed from such disturbances, the needle takes up a certain determinate position. It sets its length nearly north and south. Draw it aside from this position and let it go. After several oscillations it will again come to it. If you have obtained your magnet from a philosophical instrument-maker, you will see a mark on one of its ends. Supposing, then, that you drew your needle along the end thus marked, and that the eye-end of your needle was the last to quit the magnet, you will find that the eye turns to the south, the point of the needle turning toward the north. Make sure of this, and do not take this statement on my authority.

Now take a second darning-needle like the first, and magnetize it in precisely the same manner: freely suspended it also will turn its point to the north and its eye to the south. Your next step is to examine the action of the two needles which you have thus magnetized upon each other.

Take one of them in your hand, and leave the other suspended; bring the eye-end of the former near the eye-end of the latter; the suspended needle retreats: it is repelled. Make the same experiment with the two points. you obtain the same result, the suspended needle is repelled. Now cause the dissimilar ends to act on each other—you have attraction—point attracts eye and eye attracts point. Prove the reciprocity of this action by removing the suspended needle, and putting the other in its place. You obtain the same result. The attraction, then, is mutual, and the repulsion is mutual, and you have thus demonstrated in the clearest manner the fundamental law of magnetism, that like poles repel, and that unlike poles attract each other. You may say that this is all easily understood without doing; but *do it*, and your knowledge will not be confined to what I have uttered here.

I have said that one end of your magnet has a mark upon it; lay several silk fibres together so as to get sufficient strength, or employ a thin silk ribbon, and form a loop large enough to hold your magnet. Suspend it; it turns its marked end toward the north. This marked end is that which in England is called the north pole. If a common smith has made your magnet, it will be convenient to determine its north pole yourself, and to mark it with a file. You vary your experiments by causing your magnetized darning-needle to attract and repel your large magnet; it is quite competent to do so. In mag-

netizing the needle I have supposed the eye-end to be the last to quit the marked end of the magnet: that end of the needle is a south pole. The end which last quits the magnet is always opposed in polarity to the end of the magnet with which it has been in contact. Brought near each other they mutually attract, and thus demonstrate that they are unlike poles.

You may perhaps learn all this in a single hour; but spend several at it, if necessary; and remember, understanding it is not sufficient: you must obtain a manual aptitude in addressing Nature. If you speak to your fellow-man, you are not entitled to use jargon. Bad experiments are jargon addressed to Nature, and just as much to be deprecated. A manual dexterity in illustrating the interaction of magnetic poles is of the utmost imporance at this stage of your progress, and you must not neglect attaining this power over your implements. As you proceed, moreover, you will be tempted to do more than I can possibly suggest. Thoughts will occur to you which you will endeavor to follow out; questions will arise which you will try to answer. The same experiment may be twenty things to twenty people. Having witnessed the action of pole on pole through the air, you will perhaps try whether the magnetic power is not to be screened off. You use plates of glass, wood, slate, pasteboard, or gutta-percha, but find them all pervious to this wondrous force. One magnetic pole acts upon another through these bodies as if they were not present. And should you become a patentee for the regulation of ships' compasses, you will not fall, as some projectors have done, into the error of screening off the magnetism of the ship by the interposition of such substances.

If you wish to teach a class you must contrive that the effects which you have thus far witnessed for yourself shall be witnessed by twenty or thirty pupils. And here your private ingenuity must come into play. You will attach bits of paper to your needles, so as to render their movements visible at a distance, denoting the north and south poles by different colors, say green and red. You may also improve upon your darning-needle. Take a strip of sheet-steel, the rib of a lady's stays will answer, heat it to vivid redness and plunge it into cold water. It is thereby hardened—rendered, in fact, almost as brittle as glass. Six inches of this, magnetized in the manner of the darning-needle, will be better able to carry your paper indexes. Having secured such a strip, you proceed thus:

Magnetize a small sewing-needle and determine its poles; or, break half an inch or an inch off your magnetized darning-needle, and suspend it by a fine silk fibre. The sewing-needle or the fragment of the darning-needle is now to be used as a test-needle to examine the distribution of the magnetism in your strip of steel. Hold the strip upright in your left hand, and cause the test-needle to approach the lower end of your strip; one end is attracted the other is repelled. Raise your needle along the strip; its oscillations which at first were quick, become slower; opposite the middle of the strip they cease entirely; neither end of the needle is attracted; above the middle the test-needle turns suddenly round, its other end being now attracted. Go through the experiment thoroughly; you thus learn that the entire lower half of the strip attracts one end of the needle, while the entire upper half attracts the opposite end. Supposing the north end of your little needle to be that attracted below, you infer that the entire lower half of your magnetized strip exhibits south magnetism, while the entire upper half exhibits north magnetism. So far, then, you have determined the distribution of magnetism in your strip of steel.

You look at this fact, you think of it: in its suggestiveness the value of the experiment chiefly consists. The thought arises, "What will occur if I break my strip of steel across in the middle? Shall I obtain two magnets, each possessing a single pole?" Try the experiment; break your strip of steel, and test each half as you tested the whole. The mere presentation of its two ends in succession to your test-needle suffices to show you that you have *not* a magnet with a single pole, that each half possesses two poles with a neutral point between them. And if you again break the half into two other halves, you will find that each quarter of the original strip exhibits precisely the same magnetic distribution as the strip itself. You may continue the breaking process; no matter how small your fragment may be, it still possesses two opposite poles and a neutral point between them. Well, your hand ceases to break where breaking becomes a mechanical impossibility: but does the mind stop there? No: you follow the breaking process in idea when you can no longer realize it in fact; your thoughts wander amid the very atoms of your steel, and you conclude that each atom is a magnet, and that the force exerted by the strip of steel is the mere summation or resultant of the forces of its ultimate particles.

Here, then, is an exhibition of power which we can call forth or cause to disappear at pleasure. We magnetize our strip of steel by drawing it along the pole of a magnet: we can demagnetize it, or reverse its magnetism, by properly drawing it along the same pole in the opposite direction. What, then, is the real nature of this wondrous change? What is it that takes place among the atoms of the steel when the substance is magnetized? The question leads us beyond the region of sense, and into that of imagination. This faculty, indeed, is the divining-rod of the man of science. Not, however, an imagination which catches its creations from the air, but one informed and inspired by facts, capable of seizing firmly on a physical image as a principle, of discerning its consequences, and of devising means whereby these forecasts of thought may be brought to an experimental test. If such a principle be adequate to account for all the phenomena, if from an assumed cause the observed facts necessarily follow, we call the as-

sumption a theory, and, once possessing it, we can not only revive at pleasure facts already known, but we can predict others which we have never seen. Thus, then, in the prosecution of physical science, our powers of observation, memory, imagination, and inference, are all drawn upon. We observe facts and store them up ; imagination broods upon these memories, and by the aid of reason tries to discern their interdependence. The theoretic principle flashes, or slowly dawns upon the mind, and then the deductive faculty interposes to carry out the principle to its logical consequences. A perfect theory gives dominion over natural facts ; and even an assumption which can only partially stand the test of a comparison with facts, may be of eminent use in enabling us to connect and classify groups of phenomena. The theory of magnetic fluids is of this latter character, and with it we must now make ourselves familiar.

With the view of stamping the thing more firmly on your minds, I will make use of a strong and vivid image. In optics, red and green are called complementary colors ; their mixture produces *white*. Now I ask you to imagine each of these colors to possess a self-repulsive power ; that red repels red, and that green repels green : but that red attracts green and green attracts red, the attraction of the dissimilar colors being equal to the repulsion of the similar ones. Imagine the two colors mixed so as to produce white, and suppose two strips of wood painted with this white ; what will be their action upon each other ? Suspend one of them freely as we suspended our darning-needle, and bring the other near it ; what will occur ? The red component of the strip you hold in your hand will repel the red component of your suspended strip, but then it will attract the green ; and the forces being equal they neutralize each other. In fact, the least reflection shows you that the strips will be as indifferent to each other as two unmagnetized darning-needles would be under the same circumstances.

But suppose, instead of mixing the colors, we painted one half of each strip from centre to end red, and the other half green, it is perfectly manifest that the two strips would now behave toward each other exactly as our two magnetized darning-needles—the red end would repel the red and attract the green, the green would repel the green and attract the red ; so that, assuming two colors thus related to each other, we could by their mixture produce the neutrality of an unmagnetized body, while by their separation we could produce the duality of action of magnetized bodies.

But you have already anticipated a defect in my conception ; for if we break one of our strips of wood in the middle we have one half entirely red and the other entirely green, and with these it would be impossible to imitate the action of our broken magnet. How, then, must we modify our conception ? We must evidently suppose *each atom of wood* painted green on one face and red on the opposite one. If this were done the resultant action of all the atoms would exactly resemble the action of a magnet. Here, also, if the two opposite colors of each atom could be caused to mix so as to produce white, we should have, as before, perfect neutrality.

Substitute in your minds for these two self-repellant and mutually attractive colors two invisible self-repellant and mutually attractive fluids, which in ordinary steel are mixed to form a neutral compound, but which the act of magnetization separates from each other, placing the opposite fluids on the opposite faces of each atom, and you have a perfectly distinct conception of the celebrated theory of magnetic fluids. The strength of the magnetism excited is supposed to be proportional to the quantity of neutral fluid decomposed. According to this theory nothing is actually transferred from the exciting magnet to the excited steel. The act of magnetization consists in the forcible separation of two powers which existed in the steel before it was magnetized, but which then neutralized each other by their coalescence. And if you test your magnet after it has excited a hundred pieces of steel, you will find that it has lost no force—no more, indeed, than I should lose had my words such a magnetic influence on your minds as to excite in them a strong resolve to study natural philosophy. I should, in fact, be the gainer by my own utterance and by the reaction of your strength ; and so also the magnet is the gainer by the reaction of the body which it magnetizes.

Look now to your excited piece of steel ; figure each atom to your minds with its opposed fluids spread over its opposite faces. How can this state of things be permanent ? The fluids, by hypothesis, attract each other : what then, keeps them apart ? Why do they not instantly rush together across the equator of the atom, and thus neutralize each other ? To meet this question, philosophers have been obliged to infer the existence of a special force which holds the fluids asunder. They call it *coercive force ;* and it is found that those kinds of steel which offer most resistance to being magnetized, which require the greatest amount of coercion to tear their fluids asunder, are the very ones which offer the greatest resistance to the reunion of the fluids after they have been once separated. Such kinds of steel are most suited to the formation of *permanent* magnets. It is manifest, indeed, that without coercive force a permanent magnet would not be at all possible.

You have not forgotten that, previous to magnetizing your darning-needle, *both* its ends were attracted by your magnet ; and that both ends of your bit of iron wire were acted upon in the same way. Probably also long before this you will have dipped the end of your magnet among iron filings, and observed how they cling to it, or into a nail-box, and found how it drags the nails after it. I know very well that if you are not the slaves of routine, you will have by this time

done many things that I have not told you to do, and thus multiplied your experience beyond what I have indicated. You are almost sure to have caused a bit of iron to hang from the end of your magnet, and you have probably succeeded in causing a second piece to attach itself to the first, a third to the second; until finally the force has become too feeble to bear the weight of more. If you have operated with nails, you may have observed that the points and edges hold together with the greatest tenacity ; and that a bit of iron clings more firmly to the corner of your magnet than to one of its flat surfaces. In short, you will, in all likelihood, have enriched your experience in many ways without any special direction from me.

Well, the magnet attracts the nail, and that nail attracts a second one. This proves that the nail in contact with the magnet has had the magnetic quality developed in it by that contact. If it be withdrawn from the magnet, its power to attract its fellow-nail ceases. Contact, however, is not necessary. A sheet of glass or paper, or a space of air, may exist between the magnet and the nail ; the latter is still magnetized, though not so forcibly as when in actual contact. The nail then presented to the magnet is itself a temporary magnet. That end which is turned toward the magnetic pole has the opposite magnetism of the pole which excites it ; the end most remote from the pole has the same magnetism as the pole itself, and between the two poles the nail, like the magnet, possesses a magnetic equator.

Conversant as you now are with the theory of magnetic fluids, you have already, I doubt not, anticipated me in imagining the exact condition of the iron under the influence of the magnet. You picture the iron as possessing the neutral fluid in abundance ; you picture the magnetic pole, when brought near, decomposing the fluid ; repelling the fluid of a like kind with itself, and attracting the unlike fluid ; thus exciting in the parts of the iron nearest to itself the opposite polarity. But the iron is incapable of becoming a permanent magnet. It only shows its virtue as long as the magnet acts upon it. What, then, does the iron lack which the steel possesses ? It lacks coercive force. Its fluids are separated with ease, but, once the separating cause is removed, they flow together again, and neutrality is restored. Your imagination must be quite nimble in picturing these changes. You must be able to see the fluids dividing and reuniting according as the magnet is brought near or withdrawn. Fixing a definite pole in your imagination, you must picture the precise arrangement of the two fluids with reference to this pole. And you must not only be well drilled in the use of this mental imagery yourself, but you must be able to arouse the same pictures in the minds of your pupils, and satisfy yourself that they possess this power of placing actually before themselves magnets and iron in various positions, and describing the exact magnetic state of the iron in each particular case. The mere facts of magnetism will have their interest immensely augmented by an acquaintance with those hidden principles whereon the facts depend. Still, while you use this theory of magnetic fluids to track out the phenomena and link them together, be sure to tell your pupils that it is to be regarded as a symbol merely—a symbol, moreover, which is incompetent to cover all the facts,* but which does good practical service while we are waiting for the actual truth.

This state of excitement into which the soft iron is thrown by the influence of the magnet, is sometimes called "magnetization by influence." More commonly, however, the magnetism is said to be "induced" in the soft iron, and hence this way of magnetizing is called "magnetic induction." Now, there is nothing theoretically perfect in Nature : there is no iron so soft as not to possess a certain amount of coercive force, and no steel so hard as not to be capable, in some degree, of magnetic induction. The quality of steel is in some measure possessed by iron, and the quality of iron is shared in some degree by steel. It is in virtue of this latter fact that the unmagnetized darning needle was attracted in your first experiment ; and from this you may at once deduce the consequence that, after the steel has been magnetized, the repulsive action of a magnet must be always less than its attractive action. For the repulsion is opposed by the inductive action of the magnet on the steel, while the attraction is assisted by the same inductive action. Make this clear to your minds, and verify it by your experiments. In some cases you can actually make the attraction due to the temporary magnetism overbalance the repulsion due to the permanent magnetism, and thus cause two poles of the same kind apparently to attract each other. When, however, good hard magnets act on each other from a sufficient distance, the inductive action practically vanishes, and the repulsion of like poles is sensibly equal to the attraction of unlike ones.

I dwell thus long on elementary principles, because they are of the first importance, and it is the temptation of this age of unhealthy cramming to neglect them. Now follow me a little further. In examining the distribution of magnetism in your strip of steel, you raised the needle slowly from bottom to top, and found what we called a neutral point at the centre. Now does the magnet really exert no influence on the pole presented to its centre ? Let us see.

Let S. N. Fig. 1 be your magnet, and let n represent a particle of north magnetism placed exactly opposite the middle of the magnet. Of course this is an imaginary case, as you can never in reality thus detach your north magnetism from its neighbor. What is

* This theory breaks down when applied to diamagnetic bodies, which are repelled by magnets. Like soft iron, such bodies are thrown into a state of temporary excitement in virtue of which they are repelled, but any attempt to explain such a repulsion by the decomposition of a fluid will demonstrate its own futility.

the action of the two poles of the magnet on *n*? Your reply will of course be that the pole S attracts *n* while the pole N repels it. Let the magnitude and direction of the attraction be expressed by the line *n m*, and the magnitude and direction of the repulsion by the line *n o*. Now the particle *n* being equally distant from S and N, the line *n o*, expressing the repulsion, will be equal to *m n*, which expresses the attraction, and the particle *n*, acted upon by two such forces, must evidently move in the direction *p n*, exactly midway between *m n* and *n o*. Hence you see that, although there is no tendency of the particle *n* to move toward the magnetic equator, there is a tendency on its part to move parallel to the magnet. If instead of a particle of north magnetism we placed a particle of south magnetism opposite to the magnetic equator, it would evi-

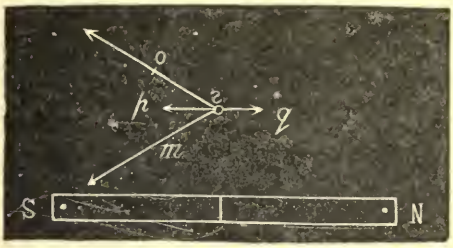


FIG. 1.

dently be urged along the line *n q*; and if instead of two separate particles of magnetism we place a little magnetic needle, containing both north and south magnetism, opposite the magnetic equator, its south pole being urged along *n q*, and its north along *n p*, the little needle will be compelled to set itself parallel to the magnet S N. Make the experiment, and satisfy yourselves that this is the case.

Substitute for your magnetic needle a bit of iron wire, devoid of permanent magnetism, and it will set itself exactly as the needle does. Acted upon by the magnet, the wire, as you know, becomes a magnet and behaves as such; it will, of course, turn its north pole toward *p*, and south pole toward *q*, just like the needle.

But supposing you shift the position of your particle of north magnetism, and bring it nearer to one end of your magnet than to the other, the forces acting on the particle are no

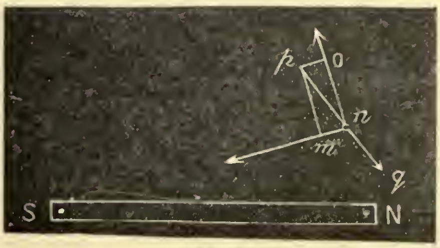


FIG. 2.

longer equal: the nearest pole of the magnet will act more powerfully on the particle than the more distant one. Let S N, Fig. 2, be the magnet and *n* the particle of north magnetism in its new position. Well, it is repelled by N, and attracted by S. Let the repulsion be represented in magnitude and direction by the line *n o*, and the attraction by the shorter line *n m*. The resultant of these two forces will be found by completing the parallelogram *m n o p*, and drawing its diagonal *n p*. Along *n p*, then, a particle of north magnetism would be urged by the simultaneous action of S. and N. Substituting a particle of south magnetism for *n*, the same reasoning would lead to the conclusion that the particle would be urged along *n q*, and if we place at *n* a short magnetic needle, its north pole will be urged along *n p*, its south pole along *n q*, and the only position possible to the needle, thus acted on, is along the line *p q*, which, as you see, is no longer parallel to the magnet. Verify this by actual experiment.

In this way we might go round the entire magnet, and considering its two poles as two centres from which the force emanates, we could, in accordance with ordinary mechanical principles, assign a definite direction to the magnetic needle at every particular place. And substituting, as before, a bit of iron wire for the magnetic needle, the positions of both will be the same.

Now, I think, without further preface, you will be able to comprehend for yourselves, and explain to others, one of the most interesting effects in the whole domain of magnetism. Iron filings you know are particles of iron, irregular in shape, being longer in some directions than in others. For the present experiment, moreover, instead of the iron filings, very small scraps of thin iron wire might be employed. I place a sheet of paper over the magnet; it is all the better if the paper be stretched on a wooden frame, as this enables us to keep it quite level. I scatter the filings, or the scraps of wire, from a sieve upon the paper, and tap the latter gently, so as to liberate the particles for a moment from its friction. The magnet acts on the filings through the paper, and see how it arranges them! They embrace the magnet in a series of beautiful curves, which are technically called magnetic curves, or lines of magnetic force. Does the meaning of these lines yet flash upon you? Set your magnetic needle or your suspended bit of wire at any point of one of the curves, and you will find the direction of the needle or of the wire to be exactly that of the particle of iron, or of the magnetic curve at the point. Go round and round the magnet; the direction of your needle always coincides with the direction of the curve on which it is placed. These, then, are the lines along which a particle of south magnetism, if you could detach it, would move to the north pole, and a bit of north magnetism to the south pole; they are the lines along which the decomposition of the neutral fluid takes place, and in the case of the magnetic needle, one of its poles being urged in one direction, and the other

pole in the opposite direction, the needle must necessarily set itself as a *tangent* to the curve. I will not seek to simplify this subject further. If there be anything obscure or confused or incomplete in my statement, you ought now, by patient thought, to be able to clear away the obscurity, to reduce the confusion to order, and to supply what is needed to render the explanation complete. Do not quit the subject until you thoroughly understand it; and if you are able to look with your mind's eye at the play of forces around a magnet, and see distinctly the operation of those forces in the production of the magnetic curves, the time which we have spent together has not been spent in vain.

In this thorough manner we must master our materials, reason upon them, and, by determined study, attain to clearness of conception. Facts thus dealt with exercise an expansive force upon the boundaries of thought; they widen the mind to generalization. We soon recognize a brotherhood between the larger phenomena of Nature and the minute effects which we have observed in our private chambers. Why, we inquire, does the magnetic needle set north and south? Evidently it is compelled to do so by the earth; the great globe which we inherit is itself a magnet. Let us learn a little more about it. By means of a bit of wax or otherwise, attach your silk fibre to your magnetic needle by a single point at its middle, the needle will thus be uninterfered with by the paper loop, and will enjoy, to some extent, a power of dipping its point or its eye below the horizon. Lay your magnet on a table, and hold the needle over the equator of the magnet. The needle sets horizontal. Move it toward the north end of the magnet; the south end of the needle dips, the dip augmenting as you approach the north pole, over which the needle if free to move, will set itself exactly vertical. Move it back to the centre, it resumes its horizontality; pass it on toward the south pole, its north end now dips, and directly over the south pole the needle becomes vertical, its north end being now turned downward. Thus we learn that on the one side of the magnetic equator the north end of the needle dips; on the other side the south end dips, the dip varying from nothing to ninety degrees. If we go to the equatorial regions of the earth with a suitably suspended needle, we shall find there the position of the needle horizontal. If we sail north, one end of the needle dips; if we sail south, the opposite end dips; and over the north or south terrestrial magnetic pole the needle sets vertical. The south magnetic pole has not yet been found, but Sir James Ross discovered the north magnetic pole on the 1st of June, 1831. In this manner we establish a complete parallelism between the action of the earth and that of an ordinary magnet.

The terrestrial magnetic poles do not coincide with the geographical ones; nor does the earth's magnetic equator quite coincide with the geographical equator. The direction of the magnetic needle in London, which is called the magnetic meridian, incloses an angle of 24 degrees with the true astronomical meridian, this angle being called the declination of the needle for London. The north pole of the needle now lies to the west of the true meridian; the declination is westerly. In the year 1660, however, the declination was nothing, while before that time it was easterly. All this proves that the earth's magnetic constituents are gradually changing their distribution. This change is very slow; it is technically called the *secular change*, and the observation of it has not yet extended over a sufficient period of time to enable us to guess, even approximately, at its laws.

Having thus discovered, to some extent, the secret of the earth's power, we can turn it to account. I hold in my hand a poker formed of good soft iron; it is now in the line of dip, a tangent, in fact, to the earth's line of magnetic force. The earth, acting as a magnet, is at this moment constraining the two fluids of the poker to separate, making the lower end of the poker a north pole, and the upper end a south pole. Mark the experiment: I hold the knob uppermost, and it attracts the north end of a magnetic needle. I now reverse the poker, bringing its knob undermost; the knob is now a north pole and attracts the south end of a magnetic needle. Get such a poker and carefully repeat this experiment; satisfy yourselves that the fluids shift their position according to the manner in which the poker is presented to the earth. It has already been stated that the softest iron possesses a certain amount of coercive force. The earth, at this moment, finds in this force an antagonist which opposes the full decomposition of the neutral fluid. The component fluids may be figured as meeting an amount of friction, or possessing an amount of adhesion, which prevents them from gliding over the atoms of the poker. Can we assist the earth in this case? If we wish to remove the residue of a powder from the interior surface of a glass to which the powder clings, we invert the glass, tap it, loosen the hold of the powder, and thus enable the force of gravity to pull it down. So also by tapping the end of the poker we loosen the adhesion of the fluid to the atoms and enable the earth to pull them apart. But what is the consequence? The portion of fluid which has been thus forcibly dragged over the atoms refuses to return when the poker has been removed from the line of dip; the iron, as you see, has become a permanent magnet. By reversing its position and tapping it again we reverse its magnetism. A thoughtful and competent teacher will well know how to place these remarkable facts before his pupils in a manner which will excite their interest; he will know, and if not, will try to learn, how, by the use of sensible images, more or less gross, to give those he teaches definite conceptions, purifying these conceptions more and more as the minds of his pupils become more capable of abstraction. He will cause his logic to run like a line of light through these images, and by thus act-

ing he will cause his boys to march at his side with a profit and a joy, which the mere exhibition of facts without principles, or the appeal to the bodily senses and the power of memory alone, could never inspire.

As an expansion of the note at page 339 the following extract may find a place here:

"It is well known that a voltaic current exerts an attractive force upon a second current, flowing in the same direction; and that when the directions are opposed to each other the force exerted is a repulsive one. By coiling wires into spirals. Ampère was enabled to make them produce all the phenomena of attraction and repulsion exhibited by magnets, and from this it was but a step to his celebrated theory of molecular currents. He supposed the molecules of a magnetic body to be surrounded by such currents, which, however, in the natural state of the body mutually neutralized each other, on account of their confused grouping. The act of magnetization he supposed to consist in setting these molecular currents parallel to each other; and, starting from this principle, he reduced all the phenomena of magnetism to the mutual action of electric currents.

"If we reflect upon the experiments recorded in the foregoing pages from first to last, we can hardly fail to be convinced that diamagnetic bodies operated on by magnetic forces possess a polarity 'the same in kind as, but the reverse in direction of, that acquired by magnetic bodies.' But, if this be the case, how are we to conceive the *physical mechanism* of this polarity? According to Coulcomb's and Poisson's theory, the act of magnetization consists in the decomposition or a neutral magnetic fluid; the north pole of a magnet, for example, possesses an attraction for the south fluid of a piece of soft iron submitted to its influence, draws the said fluid toward it, and with it the material particles with which the fluid is associated. To account for diamagnetic phenomena this theory seems to fail altogether: according to it, indeed, the oft-used phrase, 'a north pole exciting a north pole, and a south pole a south pole,' involves a contradiction. For if the north fluid be supposed to be *attracted* toward the influencing north pole, it is absurd to suppose that its presence there could produce *repulsion*. The theory of Ampère is equally at a loss to explain diamagnetic action; for if we suppose the particles of bismuth surrounded by molecular currents, then, according to all that is known of electro-dynamic laws, these currents would set themselves parallel to, and in the same direction as those of the magnet, and hence attraction, and not repulsion, would be the result. The fact, however, of this not being the case proves that these molecular currents are not the mechanism by which diamagnetic induction is effected. The consciousness of this, I doubt not, drove M. Weber to the assumption that the phenomena of diamagnetism are produced by molecular currents, not *directed*, but actually *excited* in the bismuth by the magnet. Such induced currents would, according to known laws, have a direction *opposed* to those of the inducing magnet, and hence would produce the phenomena of repulsion. To carry out the assumption here made, M. Weber is obliged to suppose that the molecules of diamagnetic bodies are surrounded by channels, in which the induced molecular currents, once excited, continue to flow without resistance."—*Diamagnetism and Magnecrystallic Action*, pp. 136, 137.

THE END.

CONTENTS.

Beacon Lights of Science

THE WONDERS OF THE HEAVENS

BY

CAMILLE FLAMMARION

FROM THE FRENCH BY MRS. NORMAN LOCKYER

WITH THIRTY-TWO ACTINOGLYPH ILLUSTRATIONS.

BOOK FIRST.

I.

NIGHT.

"O nuit! que ton langage est sublime pour moi!"*

O NIGHT, how sublime is thy language to me! . . . Where are the souls to whom the spectacle of starry night is not an eloquent discourse? Where are those who have not been sometimes arrested in the presence of the bright worlds which hover over our heads, and who have not sought for the key of the great enigma of creation? The solitary hours of night are in truth the most beautiful of all our hours, those in which we have the faculty of placing ourselves in intimate communication with great and holy Nature. Far from spreading a veil over the universe, as is sometimes said, they only efface those which the sun produces in the atmosphere. The orb of day conceals from us the splendors of the firmament; it is during the night that the panoramas of the sky are open to us. "At the hour of midnight the heavenly vault is strewn with stars, like isles of light in the midst of an ocean extending over our heads. Who can contemplate them and bring back his looks to the earth without feeling sad regrets, and without longing for wings in order to take flight and be blended with them, or be lost amid their immortal light?"

In the midst of darkness our eyes gaze freely on the sky, piercing the deep azure of the apparent vault, above which the stars shine. They traverse the white constellated regions, visiting distant regions of space, where the most brilliant stars lose their brightness by distance; they go beyond this unexplored expanse, and mount still higher, as far as those faint nebulæ whose diffused brightness seems to mark the limits of the visible. In this immense passage of sight, thought with rapid wings accompanies the forerunning visual ray, carried away by its flight and wonderingly contemplating these distant splendors. The purity of the heavenly prospect awakens that eternal predisposition to melancholy which dwells in the depths of our souls, and soon the spectacle absorbs us in a vague and indefinable reverie. It is then that thousands of questions spring up in our minds, and that a thousand points of interrogation rise to our sight. The problem of creation is a great problem! The science of the stars is an immense science; its mission is to embrace the universality of created things!

At the remembrance of these impressions, does it not appear that the man who does not feel any sentiment of admiration before the picture of the starry splendor, is not yet worthy of receiving on his brow the crown of intelligence?

Night is, in truth, the hour of solitude, in which the contemplative soul is regenerated in the universal peace. We become ourselves; we are separated from the factitious life of the world, and placed in the closest communion with nature and with truth.

Of all the sciences, Astronomy is the one which can enlighten us best on our relative value, and make us understand the relation which connects the Earth with the rest of creation. Without it, as the history of past centuries testifies, it is impossible for us to know where we are or who we are, or to establish an instructive comparison between the place which we occupy in space and the whole of the universe: without it we should be both ignorant of the actual extent of our country, its nature, and the order to which it belongs. Inclosed in the dark meshes of ignorance, we cannot form the slightest idea of the general arrangement of the world: a thick fog covers the narrow horizon which contains us, and our mind remains incapable of soaring above the daily theatre of life, and of going beyond the narrow sphere traced by the limits of the action of our senses. On the other hand, when the torch of the Science of the Worlds enlightens us, the scene changes, the vapors which darkened the horizon fade away, our mistaken eyes contemplate in the serenity of a pure sky the immense work of the Creator. The Earth appears like a globe poised under our steps; thousands of similar globes are rocked in ether; the world enlarges in proportion as the power of our examination increases, and from that time universal creation develops itself before us in its reality, establishing both our rank and our relation with the numerous similar worlds which constitute the universe.

The silence and profound peace of a starry night present an appropriate scene to our contemplative faculty, and no time is more propitious to the elevation of the soul toward the beauties of the heavens. But the poetry of the sight of these appearances will be soon surpassed by the magnificence of the reality. And it is on this point that we must first insist, in order to get rid of all delusions caused by the senses. It seems to me right to remove the causes of error which may leave false impressions on our minds; it is completely useless, if not dangerous, to devote the first part of an astronomical discourse to describing apparent phenomena, which will afterward have to be proved false. Let us not follow this troublesome road; let us keep away from the ordinary path, and begin, on the contrary, by raising the veil, in order to allow the reality to shine. Poetry, whose harmonious breath has just hushed our suspended souls, will not vanish on that account; it will rather regain a fresh aspect and new life, and, above all, a greater energy. Fiction can never be superior to truth; the latter is a source of inspiration to us, richer and more fruitful than the former.

II.

THE HEAVENS.

THE shade which spreads over the hemisphere in the absence of the Sun, from its setting to its rising, is only a partial phenomenon, circumscribed by the Earth, and in which the remainder of the universe does not participate. When we are enveloped in the calm silence of profound night, we are inclined to extend the scene which surrounds us to the entire universe, as if our world were the centre and pivot of creation. A few moments' reflection will suffice to prove how great this illusion is, and to prepare us for the conception of the whole world. It is, indeed, evident that the Sun cannot illuminate all sides of the same object at once, but only those which are turned toward it, only lighting up half the terrestrial globe at one time; hence it follows that night is nothing more than the state of the non-luminous part. If we imagine the terrestrial globe suspended in space, we shall understand that the side turned toward the Sun is alone illuminated, while the opposite hemisphere remains in shadow, and that this shadow presents the aspect of a cone. Moreover, as the Earth turns on itself, all its portions are presented successively to the Sun and pass successively into this shadow, and it is this which constitutes the succession of day and night in every country of the world. This simple *coup d'œil* suffices to show that the phenomenon to which we give the name of night belongs really to the Earth, and that the heavens and the rest of the universe are independent of it.

This is the reason why, if at any hour of the night we let our minds soar above the terrestrial surface, it will follow that, far from remaining always in the night, we shall again find the Sun pouring forth his floods of light through space. If we carry ourselves away as far as one of the planets which, like the Earth, revolves in the region of space where we are, we shall understand that the night of the Earth does not extend to those other worlds, and that the period which with us is consecrated to repose does not extend its influence there. When all beings are buried in the stillness of silent night here—above, the forces of nature continue the exercise of their brilliant functions—the Sun shines, life radiates, movement is not suspended, and the reign of light pursues its dominant action in the heavens (as on the opposite hemisphere to ours), at the same hour when sleep overcomes all beings on the hemisphere we inhabit.

It is important that we should know, first of all, how to habituate ourselves to this idea of the isolation of the Earth in space, and to believe that all the phenomena which we observe upon this globe are peculiar to it and

foreign to the rest of the universe. Thousands and thousands of similar globes revolve like it in space. I do not now prove the truth of my assertions, but my readers will not doubt them, and will be willing to take my word, reminding me later to justify all that I shall have stated. Moreover, I promise them to do this as soon as possible; but I shall ask their permission to develop at once, in outline, a general idea of the universe.

One of the most fatal delusions which it is important we should get rid of at once, is that which presents the Earth as the lower half of the universe, and the heavens as its upper

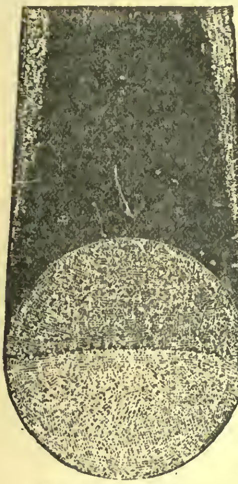


Fig. 1.—Night and Day.

half. There is nothing in the world more false than this. The heavens and the Earth are not two separate creations, as we have had repeated to us thousands and thousands of times. They are only one. The Earth is in the heavens. The heavens are infinite space, indefinite expanse, a void without limits; no frontier circumscribes them, they have neither beginning nor end, neither top nor bottom, right nor left; there is an infinity of paces which succeed each other in every direction. The Earth is a little material globe, placed in this space without support of any kind, like a bullet which sustains itself alone in the air, like the little captive balloons which rise and float in the atmosphere when the thin cord which retains them is cut. The Earth is a star in the heavens; it forms part of them; it, in company with a great many other globes similar to it, peoples them; it is isolated in them; and all these other globes also float isolated in space. This c nception of the universe is not only very important, but it is also a truth which it is absolutely necessary should be well fixed in the mind, otherwise three quarters of the astronomical discoveries would remain incomprehensible. Here, then, is this first point well understood and thoroughly established in our thoughts. The heavens surround us on every side. In this space the Earth is a globe suspended; but the Earth is not alone in space. All those stars which sparkle in the heavens are isolated globes, suns shining by their own light; they are very distant from us; but there are stars nearer which resemble much more the one we inhabit, in the sense that they are not suns, but dark earths receiving, like ours, light from our Sun. These worlds called "planets" are grouped in a family; ours is one member of this family. At the centre of this group shines our Sun, a source of light which illuminates it, and of heat which warms it. Floating in the bosom of the space which surrounds it on every side, this group is like a fleet of many boats rocked in the ocean of the heavens.

A multitude of suns, surrounded like ours with a family of which they are the foci and the light-givers, float likewise in all parts of the expanse. These suns are the stars with which the fields of heaven are scattered. In spite of the appearance caused by perspective, immense spaces separate all these systems from ours, spaces so great that the highest figures of our great numeration can scarcely number the smallest among them. A distance that our figures can scarcely express also separates these stars from each other, extending from depths unto depths.

Notwithstanding these prodigious intervals, these suns are in number so considerable that their numeration as yet exceeds all our means; millions joined to millions are inadequate to enumerate the multitude! . . . Let the mind try if it is possible to represent to itself at one time this considerable number of systems and the distances which separate them one from the other! Confused and soon humbled at the aspect of this infinite richness, it will only learn to admire in silence this indescribable wonder. Continually rising on the other side of the heavens, going beyond the distant shores of this ocean without limits, it will endlessly discover fresh new space, and new worlds will reveal themselves to our eagerness; heavens will succeed to heavens, spheres to spheres; after deserts of expanse will open other deserts, after immensities other immensities; and even when carried away without rest, during centuries, with the rapidity of thought, the soul would continue its flight beyond the most inaccessible limits that imagination could conceive—there even the infinite of an unexplored expanse would remain still open before it; the infinite of space would oppose itself to the infinite of time; endlessly rivalling, without our ever being able to take away from the other; and the spirit will be arrested, overcome with fatigue, at the entrance of infinite creation, as if it had not advanced a single step in space.

Imagination suspends its flight and is stopped humbled.

"Ye stars! bright legions that, before all time,
Camped on yon plain of sapphire, what shall tell
Your burning myriads but the eye of Him
Who bade through heaven your golden chariots wheel?
Yet who, earth-born, can see your hosts, nor feel
Immortal impulses—eternity?
What wonder if the o'erwrought soul should reel
With its own weight of thought, and the wild eye
See fate within your tracks of deepest glory lie?"*

The immensity of the heavens has been sung on many lyres; but how can the song of man express such a reality? Poets have tried to render it in verse, when one feels the insufficiency of speech to note the immense thoughts which this wonderful contemplation develops in us.

Had I not reason for stating, as I did, that reality is superior to fiction, even from the point of view poetical sentiments, and that the contemplation of actual nature incloses a richer and more fruitful source of inspiration than the illusions of the spectacle offered by our senses? Instead of an immense night stretching itself to the azure vaults, instead of a robe worked with gold embroideries, or a veil covered with brilliant ornaments, we are in the bosom of life and universal brightness. Night is but an accident, a happy accident, which enables our looks to extend themselves beyond the limits which the day marks for us; we are like a traveller reclining in the shadow of a hill, who contemplates the illuminated landscape which is unfolded as far as the distant horizon. Instead of the immobility of dead silence, we are present at the spectacle of life on worlds. With the light of truth the arbitrary vaults disappear and heaven opens its depths to us: the infinite of creation is revealed with the infinite of space, and our Earth, losing the preponderance which our pretensions had accorded to it, gives way under our feet and disappears in the shade, losing itself in the midst of a multitude of similar little worlds. In the freedom of our flight we go beyond the solar regions and take our first sketch of the universe. It is thus that, disabusing ourselves of the first step of the ancient rror too long established by appearances, we place ourselves in good condition for study, and prepare ourselves to receive easily the fresh truths which nature will reveal to us.

Allow me, in concluding this chapter, to relate an episode worthy of being more known than it has yet been, because it shows how much more power the real world has than the empire of fiction. It is taken from the life of the great mathematician, Euler, and it was Arago himself who related it to the Chambre des Députés at the meeting of the 23d of March, 1837.

"Euler, the great Euler, was very devout; one of his friends, a minister of one of the Berlin churches, came to him one day and said, 'Religion is lost, faith has no longer any basis, the heart is no longer moved, even by the sight of the beauties—the wonders of creation. Can you believe it? I have represented this creation as everything that is beautiful, poetical, and wonderful; I have quoted ancient philosophers and the Bible itself; half the audience did not listen to me, the other half went to sleep or left the church.'

"'Make the experiments which Truth points out to you,' replied Euler. 'Instead of giving the description of the world from Greek philosophers or the Bible, take the astronomical world, unveil the world such as astronomical research has constituted it. In the sermon which has been so little attended to, you have probably, according to Anaxagoras, made the Sun equal to the Peloponnesus. Very well! say to your audience that, according to exact incontestable measurements, our Sun is 1,200,000 times larger than the Earth.

"'You have, doubtless, spoken of the fixed crystal heavens; say that they do not exist, that comets break through them, in your explanations planets were only distinguished from stars by movement; tell them they are worlds, that Jupiter is 1400 times larger than the Earth, and Saturn 900 times; describe the wonders of the ring; speak of the multiple moons of these distant worlds.

"'Arriving at the stars, their distances, do not state miles; the numbers will be too great, they will not appreciate them; take as a scale the velocity of light; say that it travels 186,000 miles per second; afterward, add that there is no star whose light reaches us under three years; that there are some of them with respect to which no special means of observation has been used, and whose light does not reach us under thirty years.

"'On passing from certain results to those which have only great probability, show that, according to all appearance, certain stars could be visible several millions of years after having been destroyed; for the light which is emitted by them takes many millions of years to traverse the space which separates them from the Earth.'

"Such was, gentlemen, shortened, and only with few modifications in figures, the counsel given by Euler. The advice was followed; instead of the world of fable, the minister presented the world of science. Euler waited for his friend with impatience. He arrived at last, with dull eye and in a manner which appeared to indicate despair. The geometer, very astonished, cried out, 'What has happened?'

"'Ah! Monsieur Euler,' replied the minister, 'I am very unhappy; they have forgotten the respect which they owed to the sacred temple, they have applauded me.'"

The scientific world was a hundred orbits greater than the world which the most ardent imaginations had dreamed of. There was a thousand times more poetry in the reality than in the fable.

III.

INFINITE SPACE.

THERE are truths before which human thought feels itself humiliated and perplexed, which it contemplates with fear, and without the power to face them, although it understands their existence and necessity: such are those of the infinity of space and eternity of duration. Impossible to define, for all definition could only darken the first idea which is in us, these truths command and rule us. To try and explain them would be a barren hope; it suffices to keep them before our attention in order that they may reveal to us, at every instant, the immensity of their value. A thousand definitions have been given; we will, however, neither quote nor recall one of them. But we wish to open space before us and employ ourselves there, in trying to penetrate its depth. The velocity of a cannon-ball from the mouth of the cannon makes swift way, 437 yards per second. But this would be still too slow for our journey through space, as our velocity would scarcely be 900 miles an hour. This is too little. In nature there are movements incomparably more rapid, for instance, the velocity of light. This velocity is 186,000 miles per second. This will do better; thus we will take this means of

transport. Allow me, then, by a figure of speech, to tell you that we will place ourselves on a ray of light and be carried away on its rapid course.

Taking the Earth as our starting-point, we will go in a straight line to any point of the heavens. We start. At the end of the first second we have already traversed 186.000 miles; at the end of the second, 372,000. We continue. Ten seconds, a minute, ten minutes have elapsed—111,600,000 miles have been passed. Passing, during an hour, a day, a week, without ever slackening our pace, during whole months, and even a year, the time which we have traversed is already so long that, expressed in miles, the number of measurement exceeds our faculty of comprehension, and indicates nothing to our mind: they would be trillions, and millions of millions. But we will not interrupt our flight. Carried on without stopping by this same rapidity of 186.000 miles each second, let us penetrate the expanse in a straight line for whole years, fifty years, even a century. . . . Where are we? For a long time we have gone beyond the last starry regions which are seen from the Earth, the last that the telescope has visited; for a long time we travel in other regions, unknown and unexplored. No mind is capable of following the road passed over; thousands of millions joined to thousands of millions express nothing: at the sight of this prodigious expanse the imagination is arrested, humbled. Well! this is the wonderful point of the problem: we have not advanced a single step in space. We are no nearer a limit than if we had remained in the same place; we should be able again to begin the same course starting from the point where we are, and add to our voyage a voyage of the same extent; we should be able to join centuries on centuries in the same itinerary, with the same velocity, to continue the voyage without end and without rest; we should be able to guide ourselves in any part of space, left, right, forward, backward, above, below, in every direction; and when, after centuries employed in this giddy course, we should stop ourselves, fascinated, or in despair before the immensity eternally open, eternally renewed, we should again understand that our secular flights had not measured for us the smallest part of space, and that we were not more advanced than at our starting-point. In truth, it is the infinite which surrounds us, as we before expressed it, or the infinite number of worlds. We should be able to float for eternity without ever finding anything before us but an eternally open infinite.

Hence it follows that all our ideas on space have but a purely relative value. When we say, for instance, to ascend to the sky, to descend under the earth, these expressions are false in themselves, for being situated in the bosom of the infinite, we can neither ascend nor descend: there is no above or below; these words have only an acceptation relative to the terrestrial surface on which we live.

The universe must, therefore, be represented as an expanse without limits, without shores, illimited, infinite, in the bosom of which float suns like that which lights us, and earths like that which poises under our steps. Neither dome, nor vaults, nor limits of any kind; void in every direction, and in this infinite void an immense quantity of worlds, which we will soon describe.

IV.

GENERAL ARRANGEMENT OF THE UNIVERSE.

Stars are Distributed in Clusters.

In the bosom of infinite space, the unfathomable extent of which we have tried to comprehend, float rich clusters of stars, each separated by immense intervals. We shall soon show that all the stars are suns like ours, shining with their own light, and foci of as many systems of worlds. Now the stars are not scattered in all parts of space at hazard: they are grouped as the members of many families. If we compared the ocean of the heavens with the oceans of the Earth, we should say that the isles which sprinkle this ocean do not rise separately in all parts of the sea, but that they are united here and there in archipelagoes more or less rich. A Power as ancient as the existence of matter presided at the creation of these isles, each archipelago of which contains a great number; not one among them has risen spontaneously in an isolated region; they are all collected in tribes, most of which count their members by millions.

These rich groupings of stars have received the name of "Nebulæ." This name was given at the time of the invention of astronomical lenses, when these starry tribes were distinguished only under a diffused, cloudy aspect, which did not enable the eye to distinguish the composing stars. This appearance not revealing in any way the idea of solar clusters, it was thought that they were only phosphorescent, cosmical vapors, whirlwinds of luminous substance, or possibly primitive fluids, whose progressive condensation would in the future effect the formation of new stars. They were thought to assist at the creation of distant worlds, and sometimes, in remarking their different degrees of luminosity, people thought they could infer their relative ages, as in a forest the age of trees of the same species may be known on approach according to their size or the concentric circles which are formed each year under the bark. Thus the first nebula observed by the aid of the telescope and pointed out as an object of particular nature, the nebula of Andromeda, was considered for three centuries and a half as entirely deprived of stars. Simon Marius of Franconia, who from a musician became an astronomer—very compatible tastes, moreover—describing this oval and whitish appearance, which, more brilliant at the centre, became fainter at the edges, said that it resembled "the light of a candle (*candela*) seen at a

distance through a sheet of horn." Only a few years ago a Cambridge astronomer counted within the limits of this nebula 1500 little stars, notwithstanding which, the centre still keeps the aspect of a diffused light, in spite of the best instruments. Later, the astronomer Halley thought no more of the star-clusters. "In reality," he states, these spots are nothing more than light coming from an immense space situated in the regions of ether, filled with a diffused and luminous medium by itself." Others, again, imagined that at that spot the brightness of empyrean heaven was seen through an opening in the firmament. Derham said this, the author of astro-theology. But when optical instruments were perfected, this appearance of diffused light was transformed into a brilliant dotting ; in proportion as the power of the telescope became more searching, the number of apparent nebulæ diminished, and at present many of those which in Galileo's time were regarded as cosmical clouds are resolved into stars. To be just, it must be added that in revealing the stellar composition of the first nebulæ, the telescope showed others whose nature has only quite recently been found out ; these nebulæ remain in an indistinct state, not only on account of their prodigious distance, but because they are composed of vast cloud-masses of glowing gas.

Thus, infinite space must be represented

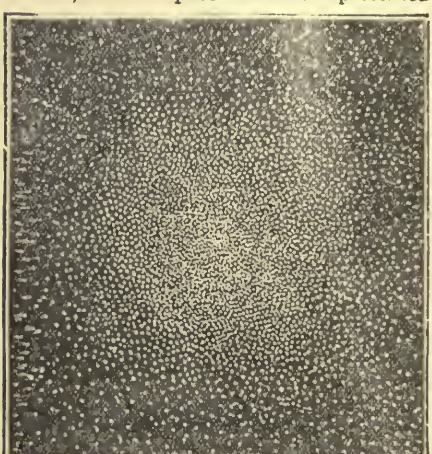


Fig. 2.—Cluster in the Centaur.

as an immense void in the bosom of which are suspended archipelagoes of stars. These archipelagoes are themselves of infinite number, the stars which compose them can be counted by millions, and from one to the other the distance is incalculable. They are distributed in space in every direction, in every sense, following every imaginable course, and themselves invested with every possible form, as we shall soon see.

One of the most remarkable and regular nebulæ, and the one that may at the same time serve best for illustrating the arguments

Fig. 3.—Globular Clusters.

which precede, is the nebula in the Centaur. We shall study farther on the aspect of the constellations and the most simple method of finding celestial objects most worthy of our attention. This nebula is presented under the following aspect in the field of a good telescope.

With the naked eye it is with difficulty distinguished as a point of faint light ; in the telescope it is seen as a prodigious number of stars strongly condensed toward the centre. This condensation is a manifest proof that the cluster of stars is not only circular, but also spherical. One instant of attention suffices indeed to show that if we look at a sphere of stars at a distance, the visual ray will pass through less if it look at the edges of the sphere than if it look at the centre, and will meet with fewer stars on its passage toward the borders than toward the centre. In proportion as this visual ray gets nearer the centre its part comprised in the sphere will become longer, and the number of stars which it will meet goes on increasing. The maximum will be at the very centre. It was this optical effect which induced the belief in a condensation of nebulous matter. Halley discovered this cluster in 1679, while he was working at the catalogue of objects visible in the Southern heavens.

The limits of this cluster are not so clearly defined as in those which have particularly received the name of globular. Fig. 3 represents some types chosen from the latter.

Of those star-clusters the first are certainly

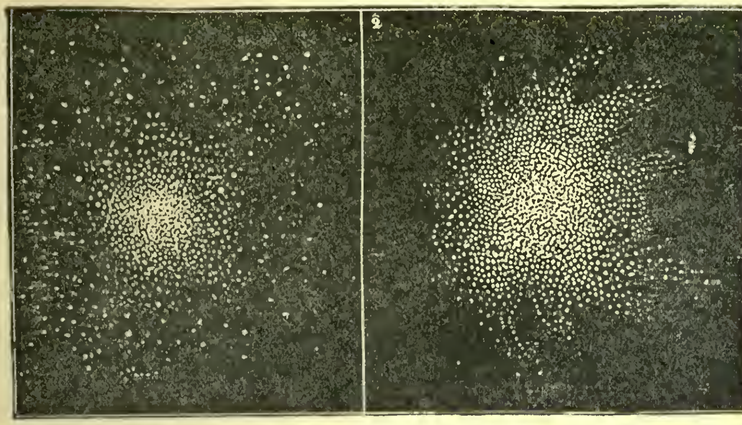


Fig. 4.—Stellar Clusters.

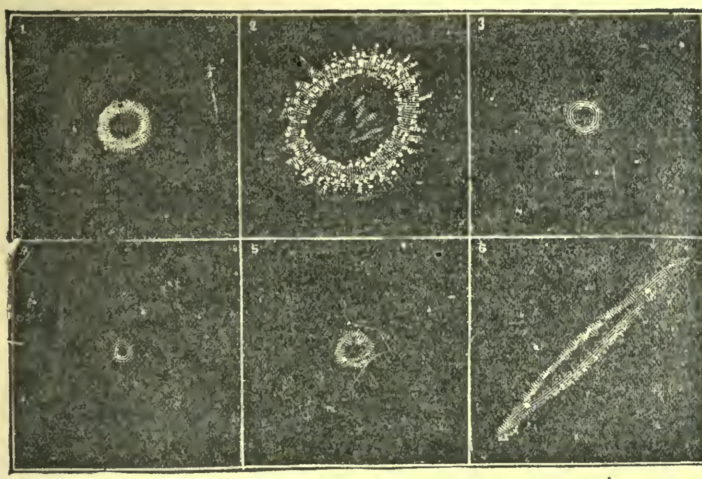


Fig. 5.—Annular Nebulæ.

spherical; others elongated, the thickness of which we see gradually diminished. These are probably also circular, but flattened in the form of lenses; instead of being presented to us in front they are seen edgeways.

At the sight of these globular masses one may ask with Arago, What is the number of stars contained in some of these clusters? The astronomer himself replied to his question. It would be impossible to count in detail and accurately the total number of stars of which certain globular nebulæ are composed; but one may be able to arrive at limits. In calculating the angular space of the stars situated near the edges, that is to say, in the region where they do not project on each other, and comparing them with the total diameter of the group, it is certain that a nebula, whose apparent superficial extent is scarcely equal to the tenth of that of the lunar disk, does not contain less than 20.000 stars; this is the minimum. The dynamic conditions proper to insure the indefinite preservation of a similar multitude of stars does not seem easy to imagine, adds the celebrated astronomer. Supposing the system at rest, the stars in time will fall on each other. Giving it a rotatory movement round a single axis, shocks will inevitably take place. After all, is it certain *à priori* that the globular systems of stars must be preserved indefinitely in the state in which we now see them?

The examination of changes which have taken place in other systems led to the belief, on the contrary, that there is nothing infinitely stable there, and that movement governs these clusters of suns, as well as it gov-

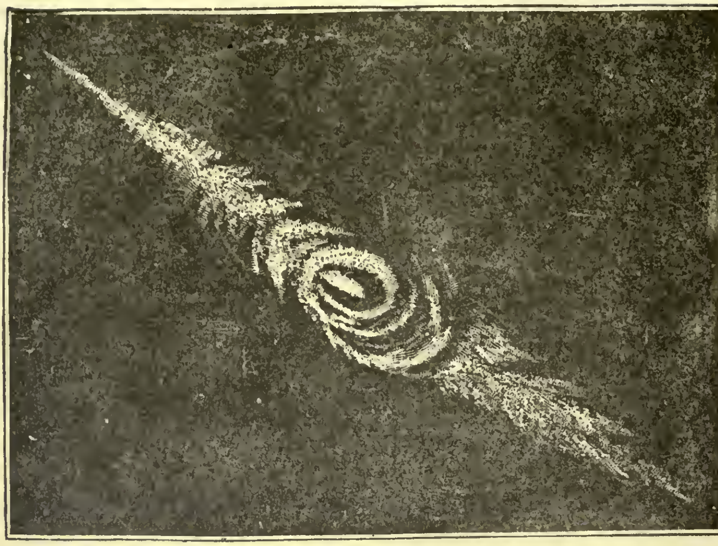


Fig. 6.—Nebula in the Lion.

Fig. 7.—Crab Cluster in the Bull

erns each of the stars, and each of the little worlds which revolve round them.

The most regular nebulæ are not the most curious; notwithstanding, the aspect of some of them leaves a certain wonder in the mind. There are star-clusters which, instead of being condensed in an immense globe, are distributed in a crown, presenting the appearance of a circular or oval nebula but hollow at its centre. Two types of this kind are represented in Figs. 5 and 6.

The first is the perforated nebula of *Lyra*; the second is that of Andromeda. In the one, the magnificent telescope of Lord Rosse shows dazzling borders of stars close together, and luminous fringes notching the outer edge; in the other, two suns, symmetrically placed on one side and the other of the ellipse, appear destined to the government of this system in its passage through space. Perforated nebulæ, says A. de Humboldt, are one of the rarest curiosities. That of Lyra is the most celebrated; it was discovered in 1779, at Toulouse, by Arquier, at the time when the comet pointed out by Bode approached the region that it occupied. It is about the apparent size of the disk of Jupiter, and forms an ellipse, its two diameters being in the ratio of four to five. The interior of the ring is not dark, but slightly luminous. The hollow space is, however, of a very deep black in the beautiful perforated

nebulæ of the Southern hemisphere. All are probably star-clusters in form of rings.

The interesting nebula sketched on 58th page (Fig. 6) will serve us as a transition between the regular and irregular nebulæ; it is the elliptic annular cluster in the Lion. It appears to possess a central nucleus of great condensation. This nucleus is enveloped with concentric spheres, more or less filled with stars, separated from each other by spaces, and these envelops succeed each other along a great axis, getting farther from the centre, diminishing in extent equally on all sides, as far as the point where they fade away in a cone.

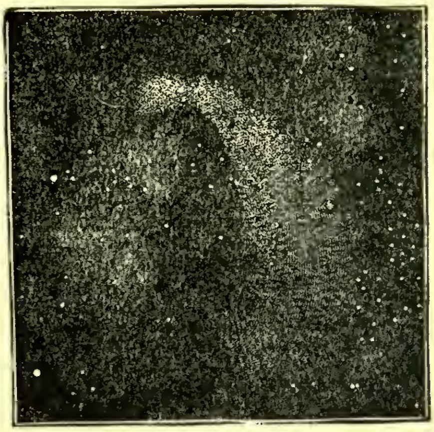


Fig. 8.—The Ship Argo.

V.

CLUSTERS AND NEBULÆ—(CONTINUED).

In proportion as the magnifying power of telescopes is increased, the contour of these

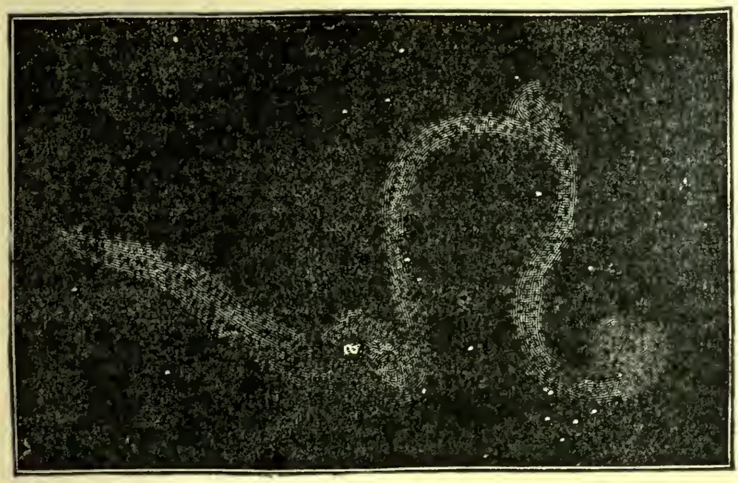


Fig. 9.—Sobieski's Crown.

star-clusters, like their interior aspect, presents itself under a more and more irregular form. Such of these objects which formerly appeared purely circular or elliptical have since showed great irregularlity in their form as well as in the degree of their luminosity. In the place where pale and whitish clouds gave out a calm and uniform light, the giant eye of the telescope has discovered alternately dark and luminous regions. The figures we are about to give all tend to support this remark; others confirm it in a still more striking manner. For instance, there is in the zodiacal constellation of the Bull a uniform and oval nebula, which does not present the least singularity in instruments of small power; but when Lord Rosse pointed his telescope to it for the first time, he could not resist immediately giving it the singular name of the Crab nebula, which its form alone suggested. The ellipse was changed into a fish; the antennæ, claws, and tail were depicted on the black sky by a white outline, formed by long trains of stars.

There are irregular clusters and nebulæ of every possible shape, and of the thousands which have been already observed, described, and sketched, no two of them have been found to resemble each other. They take the most extraordinary forms. Some present the aspect of real comets; the nucleus is accompanied with a large tail and long luminous train: these are in the Unicorn, the River Eridanus, and the Great Bear; and especially that in the Ship Argo, in which is again found the classical type of the most regular comets. Others, like that in Orion, most celebrated by the study which has distinguished it, or like that of the Magellanic

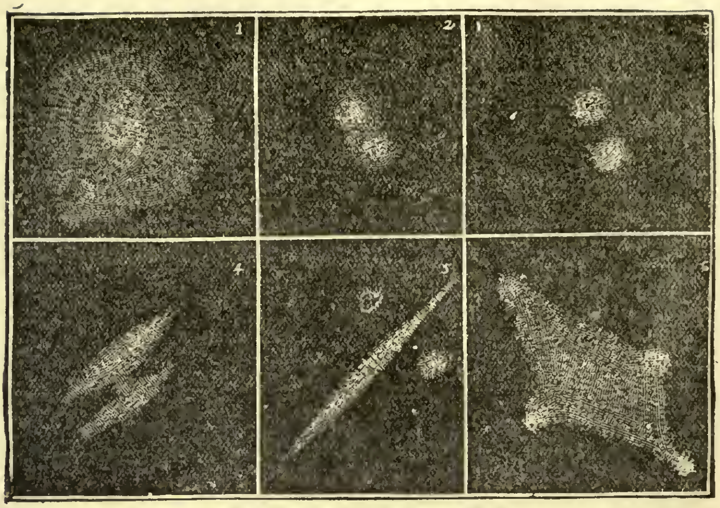


Fig. 10.—Donble and Mnltiple Nebnlæ.

Clouds and in the Ship (η), appear like immense vaporous clouds tossed about by some rough winds, pierced with deep rents, and broken in jagged portions. Another, again (that in the Fox), resembles the dumb-bells which gymnasts lift up to exercise the power of the arms; that in Sobieski's Crown describes on the page of heaven the last capital of the Greek alphabet, Ω.

Other nebulæ are grouped together, as if two or three of these vast systems had united their destinies. Many are double; we see two spherical masses united by the diffused glow which envelopes them, or they may be separated by a slight angular distance, or sometimes even inclosed in luminous concentric strata, like two eggs of snow in the midst of a nest of light. Again, elsewhere, in the Magellanic Clouds in the Southern hemisphere, we see four circular nebulæ arranged at the four angles of a lozenge, itself illuminated with fine star-dust; at one of the extreme angles the nebula is itself divided into four globes, so that in reality we have before us an immense cluster of stars, of which the extreme limits present seven principal condensations. But this is not all. Not only do these distant systems, some of them peopled with myriads of suns, take the most varied forms, not only do they present a diversity of aspect greater than it is possible to imagine; but some of them also unfold to the astonished eye which contemplates their varied shades and real colors. One is of a beautiful indigo blue; another is rose-colored at its centre with a white border, another again emits magnificent sky-blue rays. This coloring is produced by the actual color of the stars which compose it.* Others have been seen whose luminous intensity has perceptibly varied; the brightness of one of them has faded to such a degree as to be rendered completely invisible.

It is difficult to describe the impression which the sight of these distant universes makes on the mind when one sees them through the wonderful telescopes of modern times. The rays of light which reach us from so far place us for the time in communication with these strange creations, and the sentiment of terrestrial life hushed in the silence of night seems governed by the influence which celestial contemplation so easily exercises on the captivated soul. Earthly things lose their value, and one joins willingly with the voice of the poet of the Irish Melodies:

> "There's nothing bright but heaven,
> And false the light on glory's plume,
> As fading hues of even;
> And Love and Hope and Beauty's bloom,
> Are blossoms gathered for the tomb;
> There's nothing bright but heaven."

One feels that, in spite of the unfathomable distance which separates our abode from these far-off dwellings, there are there luminous foci and centres of movement: it is not a void, it is not a desert; it is "something," and this something suffices to attract our attention and awaken our reverie. An indefinable impression is communicated to us by the stellar rays which descends silently from unexplored abysses; one feels it without analyzing it, and the traces of it remain ineffaceable, like those felt by a traveller when he steps on strange lands, and sees new skies above his head. This is described by the illustrious author of "Cosmos," when he presents the Magellanic Clouds, vast nebulæ close to the Southern pole, as a unique object in the world of celestial phenomena. "The magnificent zones of the Southern heavens, comprised between the parallels from fifty and eighty degrees, are the richest in nebulous stars and irreducible nebulous clusters. Of the two Magellanic Clouds which lie near the Southern pole, this pole so poor in stars that it might be called a waste country, the largest especially appears, according to re-

Fig. 11.—Spiral Nebula in the Constellation of the Hunting Dogs.

cent researches, to be a wonderful agglomeration of spherical clusters of large and small stars, and irreducible nebulæ, whose general brightness lights up the field of sight and forms the background of the picture. The aspect of these Clouds, the brilliant constellation of the Ship Argo, the Milky Way, which extends between the Scorpion, Centaur, and Cross, and the picturesque aspect of the whole Southern sky, have produced on my mind an ineffaceable impression." Nevertheless, the most magnificent and eloquent aspect of the nebulæ has not yet been revealed to us by those which precede. To form an idea of the importance of these objects, and to appreciate their value, from the space which they occupy, also from the time which has been necessary for their formation, we must see the splendid spiral nebulæ which the powerful telescope at Parsonstown unveils to us, and which in ordinary instruments only present appearances similar to those we have already noticed.

Lord Rosse, indeed, was the first to discover that the vast systems of suns were clustered, not only simply round a centre of condensation, not only in masses more or less regular, but according to a distribution which reveals the existence of gigantic forces in action among them. He observed some immense agglomerations of which the composing stars were distributed in long lines in a general system of spiral curves.

From the principal centre springs a multitude of luminous spirals, formed of a numberless quantity of suns or nebulous masses, shaping the resplendent nucleus, whence they issue to be lost in the distance, imperceptibly parting with their brightness, and dying away as trains of phosphorescent vapors. A secondary nucleus brings up on one side the extremities of the longest spirals

There are splendid bands of constellated light, terminated with two rounded nodes. This rich spiral nebula belongs to the constellation of the Hunting Dogs. Before the discovery due to the powerful telescope which removed the veil with which it was enveloped, the best instruments only showed it as a single ring, one half of its contour surrounding a very bright globular nebula at its centre. Beyond the ring was noticed a second very small round nebula. Never was change of form more manifested between the aspects revealed by telescopes of different powers. To imagine the myriads of centuries necessary to the formation of these immense systems would be a vain undertaking. It is with slowness that nature accomplishes its most tremendous operations. In order that cosmical matter or the prodigious assemblage of so many stars could be distributed according to the curves revealed by the telescope, and winding round each other in gigantic spirals under the governing action of the combined attraction of all parts which compose this universe, it would require an incalculable series of accumulated years to pass away. Here especially it is truth to say that the luminous rays which descend from those distant creations are to us the most ancient testimony of the existence of matter.

The spiral nebula of the Hunting Dogs is not the only one of this form. In the constellation of the Virgin, Lion, and Pegasus, we also admire similar systems. That in the Virgin, situated in the central ring of Fig. 12, is presented under the aspect of the "wheels" that we see in fireworks; from the luminous centre white trains of light wind round, all guided and curved in the same direction; dark spaces separate them and give more clearness to the sketching of their direction. That in the Lion presents a series of oval concentric zones enveloping the centre, also more luminous; numerous stars shine out in the centre. The spiral nebula of Pegasus, marked with a beautiful star at its central point, is circular, and composed of circles alternately dark and luminous; on one side the circumference is cut by a tangent, a wide line of light longer than the nebula itself to which this appears to be attached, like the little silken nests of insects on branches. In writing these lines I am reminded of the year 1702, in which a maker of systems wrote a large book proving that the universe is a large spiral. According to him, God was placed at the centre of the heavens; from this centre He would communicate with all other created beings by an infinity of spiral lines directed toward the circumference. Sun and worlds, bodies and spirits, all would move in a spiral. If this singular author were again born in our day, with what delight would he seize our spiral nebulæ to illustrate his thesis!

Nebulæ are not uniformly spread in all regions of the sky. On the starry sphere vast localities may be observed where no nebula is visible, while, in other parts, they appear really heaped up.

The richest region of the heavens is in the following group of constellations, which will soon be recognized: the Great Bear, Cassiopea, Berenice's Hair, the Virgin. In the zodiacal region, near the Virgin, in an hour may be seen more than three hundred nebulæ; while, in the opposite region, a hundred would not be met with. The spaces which precede or follow nebulæ contain few stars. Herschel found this rule constant—so constant, in fact, that each time during a certain period no star was brought in the field of his immovable telescope by the movement of the heavens, he used to say to his secretary who assisted him, "Get ready to write; nebulæ are coming."

From this fact, namely, that the spaces poorest in stars are near the richest nebulæ, and from the other, that stars are generally more condensed toward the centre of nebulæ, follows a confirmation of what we said before on the incessant work of many centuries which would be required to elaborate these systems. There is nothing astonishing that these powerful unions were formed either at the expense of the surrounding cosmical matter, destined to be condensed in stars, or at the expense of the stars themselves, and that the spaces which surround them resemble vast deserts or regions laid waste.

VI.

THE MILKY WAY.

We have seen that the universe is formed of clusters and nebulæ, spread in the immensity of space, at every imaginable depth and in every possible direction. But then, if there are only nebulæ in space, and if no heavenly body is isolated from these clusters, our Earth, then, forms part of a nebula. The inhabitant of the terrestrial globe, then, finds himself also in the bosom of one of those immense clusters of stars which constitute the archipelagoes of the celestial ocean. And we do not, therefore live, as appearances lead us to suppose, beyond this starry creation which shines over our heads. In a word, if all the celestial bodies are united in groups, the Earth, then, also belongs to a group of stars, and a cluster.

Yes. The Earth, like all the stars, forms part of a cluster! It is not isolated in the deserts of the infinite; it is not an exception to the general law. The Earth, like the planets which are near it, belongs to the Sun. This Sun represents them in the universal numbering of the stars, for neither Earth nor planets count in the number of these splendors, and this Sun is one of the stars composing an immense nebula.

The Sun is but a star! This assertion seems astonishing at first sight, on account of the illusions produced by the senses. The torch of our light, the focus of heat, the ruler of terrestrial life, appears to us under the legitimate prestige of its own power, and we bow to it as the prince of stars, as the first among the great ones of the heavens. And for us, indeed, it supremely deserves these titles, and all those which our just

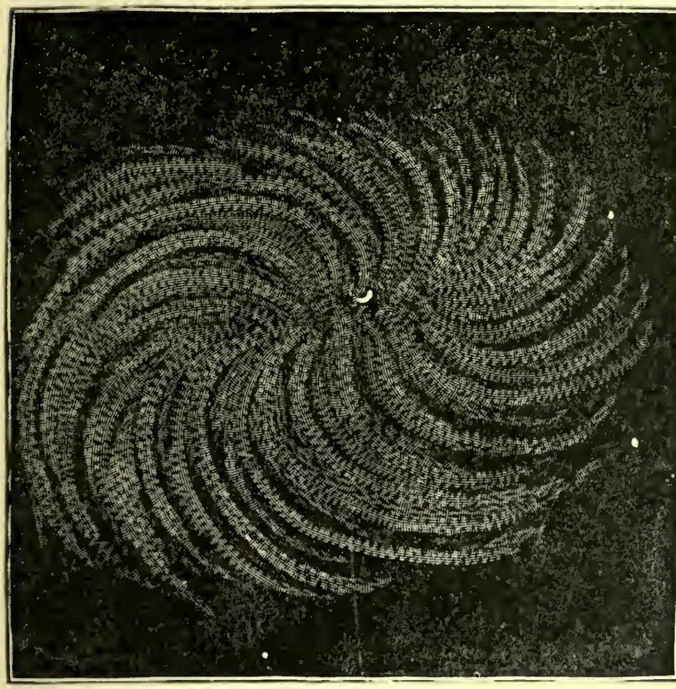


Fig. 12.—Spiral Nebula in the Virgin.

knowledge pleases to attribute to it. But if we consider it superior to the stars, if we find it more important, more magnificent, and more necessary, it is only because we are nearer to it, because in reality we are its tenants, its subjects, and that, contrary to that which happens on Earth, we recognize with delight the superiority of our master in the celestial realm. Belonging to him, we live at his expense, real parasites, and without him we should fall at once into the shades of death. To thank him and recognize his power is only just. Nevertheless, to judge things from an absolute point of view, we must rise above any particular dependence which may oppose the justice of our judgment, like him who, placed in the interior of an edifice and wishing to ascertain the rank of this edifice in the town, goes to a distance from it, and, placing himself on high ground, compares the various edifices with each other. We must, in the same way, put aside solar rule, and transport ourselves in spirit to a distant point in space, whence we should be able to determine the rank occupied by our Sun in the sidereal world.

Now, on getting farther from the Sun toward any point in space, we shall see the Sun diminish in size and lose the importance which appeared to be his privilege. When we reach the limits of his system, he will then only present the aspect of a large star. On getting still farther away, we shall see it descend to a simple star. Lastly, if we go toward any star in the heavens and continue to watch the decrease of the Sun which sinks behind us in the depths of space, it will become a small star soon lost in the multitude of others ; the one we are approaching will lose, on the contrary, its small aspect, will increase, shine out, and get larger in proportion as we approach it, and will become a real sun, not less important than ours by its luminous and calorific power, and by the gifts its distributes to the planets of its domain.

Passing beyond this new sun and continuing our path, we shall behold an analogous transformation of others stars into suns ; all those toward which we shall pass successively will appear to us under this aspect, thus showing that they shine with their own light and are so many planetary foci. Lastly, when we shall have crossed these starry plains, we shall reach shores where the suns are more scarce, and soon, a desert void of stars.

To the thousand millions and thousand millions of miles we have just traversed, let us again add a certain quantity of thousands of millions, and we shall soon arrive at a favorable point for estimating the absolute rank of our Sun. Let us then suppose that we at last reach the point from which we see the suns constituting our cluster, and then returning by the way we came, we

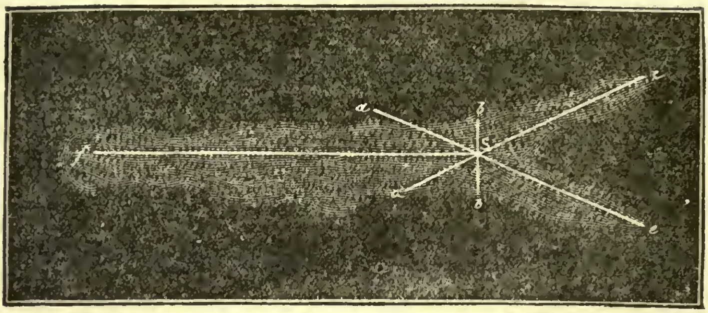


Fig. 13.—The Milky Way.

should find out what place our Sun occupies in the army of stars that we have left behind us.

It is there only that we can judge well of things. Now, this is what appears to us. All the stars which people our starry nights are inclosed in a narrow space, and we notice—now that we are beyond them—that they form a cluster of small bright points, and that they resemble an isle of lights suspended in space. In a word—and this is the point to which we wished to arrive—they form a cluster. This cluster is isolated; its limits are clearly enough defined, and no group, no star, shines in the space which surrounds it. It is marked out in the darkness in Fig. 13.

This is the nebula in which we live; this is the abode of our solar world. In what part of it are *we?* The question is at least curious, and, from the spot, where we are placed to observe the star-cluster of which we form part under its true aspect, the best instruments would not succeed in distinguishing our little Sun. But it is not always necessary to see people in order to guess where they are. This is why we are able to travel toward the centre of the nebula, and, not far from the line which separates the zone into two layers, to observe a little point. This point is the place occupied by our Sun. The Earth and planets are with him; but, since it is impossible to distinguish the Sun in the midst of this multitude, *à fortiori*, the utter impossibility of perceiving the slightest vestige of the existence of our planetary system will be manifest.

If we live thus in the middle region of a rich nebula, how is it, it may be asked by curious minds, how is it that we cannot distinguish it, and that our clear nights present around us a sky purely and splendidly starry? Is it then necessary to go away so many thousand millions of leagues from the Earth to know where it is placed? And if that is necessary, how has it been known?

No: this is not necessary, as the position is known. From the surface of our sphere we observe the sky, and we see that all around us a large nebulous circle envelopes our globe. We are ourselves near the centre of this circle, and each night displays over our heads a whitish band of dense stars continually surrounding us. This collection of stars, it has already been guessed, is the Milky Way.

The Milky Way, this wide irregular ribbon of stellar clouds which crosses the sky in all its width, is indeed nothing more than the greatest length of this immense lens of stars to which we belong. If the whole sky does not appear nebulous in every direction, it is precisely because the nebula to which we belong is not spherical, but of a lenticular form, and that in the thickness of the lens there is less depth and fewer stars than in the direction of the diameter. From the spot on which we are placed, if our sight pass through the greatest length, it meets stars on stars indefinitely, because there is an immense expanse from the point where we are to the edges of the flattened nebula. But if our sight turn aside from the equatorial plane toward the sides, it meets with fewer stars as it gets farther distant, and on reaching the polar diameter, scarcely any more will be met with. There are thirty times less stars in these regions than in those near the equatorial plane of the cluster.

All the stars which sparkle in the sky during a dark night belong to a single cluster, to a single nebula, the Milky Way marking its longitudinal direction. The stars are not isolated in an absolute manner, at random, in the deserts of space; they form part of a whole; the Sun which lights us is one of them; and they are counted by millions in a gigantic group, analogous to the distant clusters of which we have already spoken. Instead of only seeing a diffused glimmer, an indistinct light in the Milky Way, the telescope separates the stars which compose it and shows that it is formed of an innumerable multitude of stars very irregularly connected.

The idea which we must form of the Milky Way is then very different from that which appearances present to us, and from that with which the ancients contented themselves. From the beginning of ages, from the first observations of an elementary astronomy, this semi-luminous train which crosses the sky was noticed, and the ruling mythology adorned it with images.

William Herschel, with the powerful telescope made with his own hands, resolved, toward the end of the last century, to count the stars comprised in this zone : he addressed himself to his task and divided his work into portions. His long perseverance was crowned with success. By a careful comparison of the parts where the condensation of stars attains its maximum with those where it attains its minimum, and by an examination of the extent occupied by these immense rings, the great observer found that the Milky Way did not inclose less than eighteen millions of stars !

Eighteen millions of stars in the equatorial stratum of the lenticular nebula to which we belong : this is not the total number of which it is composed, as this does not refer to the lateral portions of this gigantic mass, and all the stars of the heavens situated on one side and on the other of the plane of greatest condensation are not included in this enumeration. We shall see farther on, in the chapter devoted to the study of the stars, that the total number of the members of this populous tribe is much greater still than eighteen millions. What is the real extent occupied by this collection of suns? The number of stars which compose it, and the relative distances from each other, comprises for this extent a number which the mind cannot well receive without being prepared for it, a number which it cannot appreciate without making great efforts to grapple it. I will not give the distance in leagues, because an immense continuation of leagues exceeds the limits of even the vision of the mind ; it is better to take the measure used constantly for astronomical units. Now, the extent of the Milky Way, at its greatest length, would be measured by a ray of light which, travelling 186,000 miles per second, would travel in a straight line and without stopping for fifteen thousand years.

Thus, as we are ourselves near the centre of this nebula, when in the field of a powerful telescope we observe the little distant stars situated in the depths of the Milky Way, our retina receives the impression of a luminous ray, which started seven or eight thousand years ago from a sun analogous to ours, and forming part of the same group.

If such be the extent of the nebula of which we are an infinitesimal constituent part, are not the other nebulæ scattered in space also as rich and vast ; or rather, is our nation privileged, and does it exceed the others in richness or in extent?

There is no reason to stop at this last idea, as a remnant of vanity would be perhaps able still to suggest to us, to make up a little for the mediocrity of the natural rank which we hold. The Milky Way is not unique ; many of the nebulæ of the universe are so many Milky Ways, more or less similar to our own. Some may be less vast ; others may possibly be vaster still, seeing that, in the domain of the infinite, space goes for nothing. It is best for us, then, to take the middle course, and to think that the pale and diffused nebulæ which seem to tremble in the distance in unfathomable immensities, are Milky Ways peopled with as many suns as our own. But then as they appear so small to us, they must necessarily be distant from us. More distant, indeed ; for if we find out at what distance we must remove our Milky Way in order to reduce it to the limit of a medium nebula, we find that we must remove it to 334 times its length, a distance which our agile messenger, a ray of light, takes a little more than five millions of years to accomplish. Such is the distance which may separate the gigantic clusters of suns, with which the sidereal universe is composed, and which hover in space suspended at all depths of unfathomable immensity from each other.

BOOK SECOND.

I.

THE SIDEREAL WORLD.

According to what has been previously stated, we inhabit the midst of a vast nebula ; its equatorial stratum, projecting itself on our sky, describes that cloudy zone known under the name of the Milky Way. Our Sun is one of the stars composing this gigantic cluster, and all the stars which sparkle during our silent nights form part, like him, of this same tribe. This is, properly speaking, our universe. The other nebulæ may be considered by us as other universes, foreign to this one, and which we have only contemplated in order to give us a more distinct notion of the grandeur of creation, but which we will henceforth leave in the unexplored immensity which they inhabit in the midst of space. Descending from the great to the small, proceeding from the whole to a part, we will now embrace less vast proportions ; we will pause at our sidereal universe, or, in other words, at the general description of the isles which constitute our celestial archipelago.

We will not yet speak of the nature of the stars, their distances, movements, or their particular history ; before pursuing the reality, it will be well for us to make a digression on appearances. We are, however, averse to appearances, and much prefer reality ; but there are some of which we cannot avoid speaking, seeing that they form in a certain way the surface of the things that must be searched into, and it is necessary to pass this surface before reaching the interior. But when we agree that such and such a phenomenon is only an appearance, there will be no harm in our studying it ; the important points to be understood and to avoid confusion.

The stars appear scattered at random in the heavens. In a fine starry night, when our sight rises to these heights, a great diversity in their brightness is noticed, and at the same time an apparent disorder in their general arrangement. This irregularity and the number of the stars have prevented the pos-

Fig. 14.—Constellation of the Great Bear.

sibility of giving to each of them a particular name; to recognize them and facilitate study, the heavenly sphere is divided into sections. The astronomy of the ancients, says Francœur, was confined to a few rough distinctions; they were at first contented to name the planets and most beautiful stars, and we have preserved this custom; but when they wished to study more carefully, and wished to describe stars of less brilliancy, they could only follow a method, the imperfection of which they acknowledged. They were led like the naturalists who, to name the species of the three kingdoms, unite under a common name a certain number of creatures which they afterward distinguish from each other by a qualification. Astronomers have united the stars in different groups, on which they have drawn an animal or fabulous being. To these groups or constellations they gave names from fables, history, or the animal kingdom. These denominations, consecrated by antiquity, are quite arbitrary; and unless imagination itself creates images, as it sees pictures in the ever-changing contours of the clouds, we must not endeavor to find in the groups of stars anything which might recall the figure or imitate the image of the objects whose name the constellation bears. The necessity of being guided on the seas obliged man to choose in the heavens invariable signs by which he could direct his course, and this is the historical origin of the constellations.

The ancients formed representative maps of the heavens, and from the time of Hipparchus, the Greek astronomer, they were able to class the stars, distinguishing them according to their brightness, in the positions occupied by each of them on these figures.

It was necessary to fix on a method to find a particular star easily, in the midst of such a great number (four to five thousand) as is distinguished with the naked eye. The first origin of the constellations is unknown; but it is imagined that they were established successively. The Centaur Chiron, Jason's preceptor, has the reputation of having first divided the heavens on the sphere of the Argonauts; but Job lived before the time when the precedent is placed, and this prophet then spoke of Orion, the Pleiades, and Hyades, three thousand three hundred years ago. Homer also speaks of these constellations when describing Vulcan's shield:

> "And on its surface many a rare design
> Of curious art his practiced skill had wrought,
> Thereon were figured earth, and sky, and sea,
> The ever-circling sun, and full-orbed moon,
> And all the signs that crown the vault of heav'n;
> Pleiads and Hyads, and Orion's might.
> And Arctos, call'd the Wain, who wheels on high
> His circling course, and on Orion waits;
> Sole star that never bathes in th' ocean wave."

The same mythological divisions are used in the present day. Since the establishment of Christianity there have been many efforts to reform this pagan system, and to replace it by Christian denominations. In the planisphere of Bede, St. Peter is substituted for the Ram, St. Andrew for the Bull, etc. From these attempts, no name escapes; David's chariot, Solomon's seal, the three Magi kings, or Jacob's rod, etc., date the highest. Later still, a German proposed to give to the twelve signs of the Zodiac the heraldry of the twelve most illustrious houses of Europe. These singular efforts remained sterile, and the mythological reign has continued until the present day.

As great diversity has been noticed in the brightness of stars, in order to facilitate their indication, they have been classed in order of magnitude. This word "magnitude" is improper, seeing that it has no relation to the dimensions of the stars, these dimensions being still unknown to us; it dates from a period when it was believed that the brightest stars were the largest, and this is the origin of the denomination; but it is important to know that this is not its real sense. It simply corresponds to the apparent brightness of the stars. Thus, stars of the first magnitude are those which shine with the greatest brightness in dark nights; those of the second magnitude shine less, etc. Now this apparent brightness belongs both to the real size of the star, its intrinsic light, and its distance from the Earth; consequently, it only possesses an essentially relative meaning. Nevertheless it may be said generally that the brightest stars are nearest, that those whose pale glimmer is scarcely distinguished in the field of the telescope are more distant.

Thus, when we shall speak of the magnitude of stars, it is to be understood that we refer simply to their apparent brightness; this brightness greatly facilitates the means of distinguishing them among the constellations. There is now another fact which is not less important to consider as relative,

and not as absolute ; this is the arrangement of the stars or forms of the constellations. We know already that the sky is not a concave sphere in which bright nails are fastened, and that there is no kind of vault—only immense, infinite void surrounding the Earth on all parts, and in every direction. We know, also, that the stars, suns in space, are scattered at every distance in the vast immensity. When, then, we notice two stars close together in the sky, their appar nt proximity does not in any way prove their real proximity : they may be very distant from each other, in the direction of vision, at a distance equal to or greater than that which separates us from the nearest one. In a similar way, when four, or five, or more stars are united in the same group, this does not imply that these stars, forming the same constellation, are on the same plane and at and equal distance from the Earth. By no means. Dispersed at all depths of space, all around the terrestrial atom, the arrangement which they display to our eyes is only an appearance caused by the position of the Earth with regard to them. This is purely a matter of perspective. When we find ourselves during the night in the midst of a large open space (for instance, the Place de la Concorde) in which numerous gaslights are dispersed, it is difficult for us to distinguish, at a certain distance, the most remote lights from those which are less so : they all appear to be projected on the dark ground ; moreover, their general arrangement depends purely on our point of view, and varies according as we ourselves walk away or across. This simple comparison may make us understand why the stars, lights in the dark space, do not reveal to us the distances which may really separate them, and why their arrangement on the apparent vault of the sky depends only on the spot where we place ourselves to examine them. On quitting the Earth's surface and transporting ourselves to a spot sufficiently distant, we should witness, in the apparent arrangement of the stars, a variation as much greater as our station of observation would be more distant from our previous one. For this it would be necessary to transport ourselves, not only to the last planets of our system, but beyond this system entirely, and to go to distances at least equal to those of the nearest stars. Indeed, from Neptune, the last planet of our system, the stars are seen in the same arrangement as from here. The change is only seen in quitting one star for another. One moment's reflection suffices to convince us of this fact, and to relieve us from further explanation on the subject.

These illusions once appreciated at their right value, we may, without fear, begin the description of the figures with which old fables have constellated the spheres. The knowledge of the constellations is necessary for the observation of the heavens and for researches which love of science or curiosity may inspire ; without it one finds one's self in an unknown country without any geography or possibility of discovering our whereabouts. Let us, then, form the geography of the heavens. The innumerable figures of animals, men, or objects, with which the sphere is adorned, will not, however, be drawn here, seeing that they would only serve to confuse the mind with imaginary lines. Formerly they printed celestial atlases, where the figures were represented with exquisite care, so much so, indeed, that they ended by forgetting the stars, and the sky was nothing more than a menagerie. In spite of the interest of the images, I will not follow this example. I will only give farther on, on a special map, the drawing of the constellations visible in our hemisphere. At present, let us see how to direct our course for reading correctly the great book of the heavens.

There is one constellation known to every one ; for greater simplicity we will begin with it, as it will serve us as a starting-point to go toward the others, and as a sign to find its companions. This constellation is the Great Bear, which has also been called David's Chariot, or Charles's Wain ; which the ancients called *Septem triones* (whence came the word *septentrion*), or again, *Helix Plaustrum ;* which the Greeks addressed under the name of Ἄρκτος μεγάλη, ἑλική, etc., which the Arabs called *Aldebb al Akbar*, and the Chinese, three thousand years ago, addressed as the *Tcheou-pey*, the god of the north. Thus it can boast of a high celebrity. If, however, in spite of its universal notoriety, some have not yet had occasion to make its acquaintance, the following is the sign by which it may always be recognized. Turn toward the north, that is to say, opposite the spot where the Sun is at noon. Whatever may be the season of the year, the day of the month, or hour of the night, you will always see there a large constellation formed of seven stars, four of which are quadrilateral, and at an angle with the side ; the whole arranged as in Fig. 14.

Have you not all seen it? It never sets. Night and day it watches above the northern horizon, turning slowly in four-and-twenty hours around a star of which we shall speak presently. In the figure of the Great Bear the three stars of the extremity form the tail, and the quadrilateral forms the body. In the Chariot the four stars form the wheels, and the three the car. Above the second, between these latter, good sights distinguish a very small star called Alcor, which is also called the Cavalier. The Arabs called it Saidak, which means the proof, because they used it to test a good eye. Greek letters are used to denote each star ; they are the first of the alphabet ; α and β mark the two first stars, γ and δ the two others, ϵ ζ, η, the three of the car ; Arab names have also been given to them, but I shall pass over them in silence, as they are not generally used.

This brilliant septentrional constellation, composed (with the exception of δ*) of stars of the second magnitude, has received from

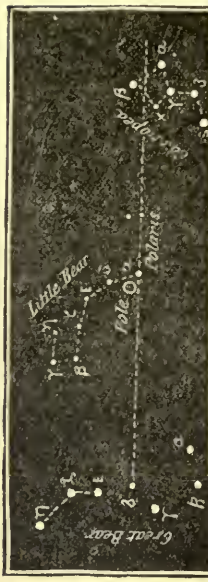


Fig. 15.—Great Bear, Little Bear, Pole Star.

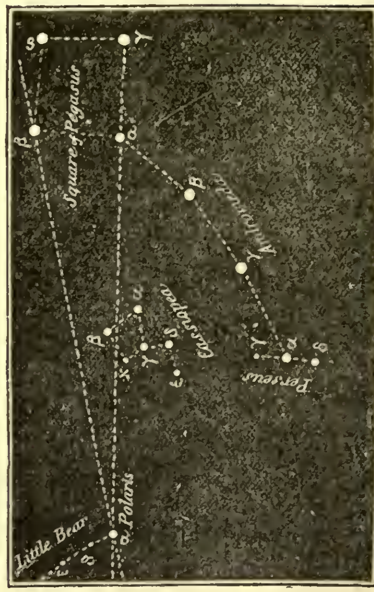


Fig. 16.—Cassiopea, Andromeda, Pegasus.

olden times the gift of captivating the attention of observers, and personating the stars of the north. Many poets have sung its praises; we will only repeat in prose one—the words being worthy of the majesty of the heavens—that of Ware, the American poet:

"With what grand and majestic steps this northern constellation advances in its eternal circle, following its royal path amidst the stars with a slow and silent light! Mighty creation, I worship thee! I love to see thee wandering in the brilliant avenues like a splendid giant with a strong belt—severe, indefatigable, and resolute, whose feet never pause on their road. Other kingdoms abandon their nocturnal path nnd rest their wearied orbs under the waves; but thou, thou never closest thy fiery eye, and never stoppest thy determined step. Forward, always forward! whilst systems change, suns set, worlds sleep and awaken, thou followest thy endless way. The adjacent horizon endeavors to arrest thee, but in vain. A vigilant sentinel, thou never quittest thy secular path, but, without allowing thyself to be overtaken by sleep, thou preservest the fixed lights of the universe, always preventing the north from forgetting its place.

"Seven stars people this bright kingdom; the sight embraces the whole; their respective distances are not inferior to their distance from the earth. And here again we see the tremendous distance between the celestial orbs. From the depths of the heavens, unexplored by the mind, the piercing rays dart through space, revealing to the senses numberless systems and worlds. Our sight must arm itself with the telescope, and explore the heavens. The heavens are opened, a rain of sparkling fire falls on our heads, stars appear close together, are condensed in such far-off regions that their rapid rays (more rapid than any other thing) have travelled for centuries in order to reach the earth. Earth, Sun, and nearest constellations, what are you amidst this infinite immensity and the multitude of divine infinite works?

These thoughts, inspired by scientific truth are superior to those of ancient mythology. Without speaking of the name of Bear, given to this constellation and the followins one, not only by the Greeks and Latins, but again by other people who did not appear to have had any communication with them, like the Iroquois, who gave to them the same name, we shall state that, generally, the Great and Little Bear were considered as Callisto and her Dog. Jupiter had a son by this nymph, the cow-herd (Boötes), of whom we shall speak farther on; he had them both placed in the sky. But the official wife of the king of gods, Madame Juno, as Virgil has said, was greatly incensed, and obtained from Thetis, the ruler of the waves, that these perfidious constellations should never bathe in the ocean. Thus their continued presence above the horizon is explained. Callisto, whose car fears the wave of Thetis, near the ice of the north, shines out near her son. The Dragon embraces them like an immense wave. According to others, the two Bears are nymphs who fed Jupiter on Mount Ida; according to others again, they represented the oxen of Icarus; but these fabulous fancies do not interest us more than they ought to do, and now that we recognize the Great Bear we must make him useful in our celestial voyages among the stars in his neighborhood and our uranographic researches generally.

Let us return to the figure before traced. If a straight line be carried through the two stars, marked α and β, which form the extremity of the square, and prolonged beyond α to an extent equal to five times the distance from β to α, or, in other words, to an

extent equal to the distance of α to the extremity of the tail η, a star less brilliant than the preceding ones is found, which forms the extremity of a figure like the Great Bear, but smaller and directed in a contrary direction. This is the Little Bear, or Little Chariot, also formed of seven stars. The star to which our line brings us, that which is at the extremity of the Bear's tail, or at the end of the shaft of the Chariot, is the Pole Star.

The Pole Star has a certain renown, like all personages who distinguish themselves from others, because, among all the stars which twinkle in our starry nights, it remains immovable in the heavens. At any moment of the year, day or night, if you observe the sky you will always find it occupying the same place. All the other stars, on the contrary, revolve round it every twenty-four hours, a hold for the centre of this immense whirlpool! The Pole Star remains immovable over one pole of the world, whence it is used as a fixed point by navigators of the pathless ocean, as well as by travellers in an unexplored desert.

Of the thousand facts which I could quote to show how many times the Pole Star, and its constellation, always visible in the north, have saved the lives of travellers lost in darkness, I shall content myself with the following, in which Albert Montemont honors the star of the north.

On the 4th of April, 1799, the English general, Baird, then at war against Tippoo Saib, received orders to march in the night, to observe a height on which it was supposed the enemy had placed an advanced post; Captain Lambton accompanied him as aide-de-camp. After having crossed this height several times, without meeting with any one, the general resolved to return to the camp, and he turned back, as it appeared to him, to the general quarters. But as the night was light and the constellation of the Great Bear was near the meridian, Captain Lambton remarked that, instead of returning south, as he must do to return to the camp, the division had advanced to the north, that is to say, toward the body of the enemy's army; and he instantly made the general aware of this mistake. But this officer, who troubled himself very little about astronomy, replied that he knew well enough what he was doing without consulting the stars. At the same instant the detachments fell in with the enemy's advanced post. This surprise having confirmed the captain's observation too well, they at first hastened to disperse the soldiers of the advanced post and then to turn back on their road. They procured a light, consulted a compass, and found, as the astronomical officer said laughingly, that the stars were right.

The immobility of the Polar Star at the north, and the movement of the entire heavens round it, are appearances caused by the movement of the Earth on its axis. We will give the evidence farther on; but, while we are visiting the country of the stars, we must not leave such a beautiful sight to descend to the Earth. Let us then continue our mode of surveying, and make ample acquaintance with the population of the starry heavens

II.

THE NORTHERN CONSTELLATIONS.

Looking at the Pole Star, stationary in the midst of the northern region, we have the south behind us, the east to the right, the west to the left. All the stars revolving round the Pole Star, from right to left, ought to be recognized according to their mutual relations rather than according to the cardinal points. On the other side of the Pole Star, relating to the Great Bear is another constellation easily recognized. If a line be brought to the pole, from the star in the middle (δ), by prolonging this line to an equal extent, the figure of Cassiopea is crossed, which is formed of five stars of the third magnitude arranged somewhat like the slanting strokes of the letter M. The little star κ, which ends the square, also gives it the form of a chair. This group takes every possible position, going round the pole; sometimes being above, sometimes below, sometimes to the left, and sometimes to the right: but it is always easy to find, seeing that, like the preceding constellation, it never sets and is always opposite to the Great Bear. The Pole Star is the axle around which these two constellations revolve.

If we now draw from the stars α and δ of the Great Bear, two lines joining the pole, and we prolong these lines beyond Cassiopea, they will lead to Pegasus, which is terminated on one side by a row of three stars similar to those of the Great Bear. These three stars belong to Andromeda, and themselves lead to another constellation, Perseus. The last star of the square of Pegasus is, as we have seen, α Andromedæ; the three others are called, γ, Algenib, α, Markab, and β, Scheat. To the north of β Andromedæ is found near a little star, ν, the oblong nebula which has been compared to the light of a candle seen through a horn plate, the first nebula of which mention is made in the annals of astronomy. In Perseus, α, the most brilliant star in the prolongation of the three principal stars of Andromeda, is seen between two others less brilliant, which with it forms a concave arc very easily distinguished. This arc will now serve us as a new starting-point. By continuing it from δ, a very brilliant star of the first magnitude is met with; this is the Capella. Forming a right angle with this prolongation to the south, we arrive at the Pleiades, a brilliant cluster of stars. On one side is a variable star, Algol, or the Head of Medusa.

The star Algol or β Persei, which is seen above α, belongs to a class of variable stars, the singular character of which we shall consider farther on. Instead of having a fixed light, as other stars, it is sometimes very brilliant and sometimes very faint; it passes from the second to the fourth mag-

nitude. It was at the end of the seventeenth century that this variability was first perceived. Observations made since that time have proved that it is periodical and regular, and that this period is of astonishing rapidity. Thus, to pass from its minimum to its maximum brilliancy, it only requires one hour and three quarters, so that in three hours and a half it has accomplished its entire cycle, has passed through all the intermediate degrees of light from the fourth to the second magnitude, and from the second to the fourth. The star ζ of Perseus is double.

Fig. 17.—The Goat, Pleiades.

These are the principal stars which people the circumpolar regions, on the one side; presently we shall make better acquaintance with them. While we are tracing lines of indication, let us have patience and finish our short examination of this part of the sky. Take now the opposite side to the one we have just considered, still near the pole. Let us return to the Great Bear. Prolonging the curve of the tail we shall find at some distance from it a star of the first magnitude; this is Arcturus, or α of the Cow-herd (Boötes). A small circle of stars that we see to the left of Boötes forms the Northern Crown.

The constellation of Boötes is traced in a pentagonal form. The stars which compose it are of the third magnitude, with the exception of α, which is of the first. This is the one nearest the Earth, for it is of the small number of those whose distance has been measured. It is situated at 1,622,800 times the radius of the Earth's orbit from us. It is, moreover, a colored star; seen with a telescope, it is red. The star ϵ, which is seen above it, is double, that is to say, the telescope separates it into two distinct stars: one being yellow, the other blue.

By bringing a line from the Pole Star to Arcturus, and erecting a perpendicular on the middle of this line, opposite to the Great Bear, we find one of the most brilliant stars of the heavens, Vega, or α of the Lyre, near the Milky Way. It forms with the two just mentioned a large equilateral triangle. The line from Arcturus to Vega cuts the constellation of Hercules. Between the Great and Little Bear, a long series of little stars is seen passing round each other in rings and directing themselves toward Vega: these are the stars of the Dragon.

The stars bordering on the pole, and which have therefore received the name of Circumpolar Stars, are distributed into the groups we have just described. Now that we easily know how to find them in the sky, we may speak a little of their ancient renown. In this group there is one of the greatest dramas of ancient mythology. To repeat this famous episode in a few words, I will mention that Cassiopea, wife of Cepheus, King of Ethiopia, one day had the vanity to believe herself more beautiful than the Nereides, in spite of the African color of her complexion. These sensitive nymphs, piqued to the quick by such pretensions, prayed Neptune to avenge them of such a gigantic affront; the god allowed fearful ravages to be made by a sea-monster on the coasts of Syria. To stay the plague, Cepheus chained his daughter, Andromeda, to a rock and offered her in sacrifice to the terrible monster. But young Perseus, touched with so much misfortune, quickly bestrode the horse Pegasus, a model of coursers, took in his hand the Medusa's head, which froze the beholder with fright, and started for the fatal rock. He arrived naturally just at the moment when the monster was going to devour

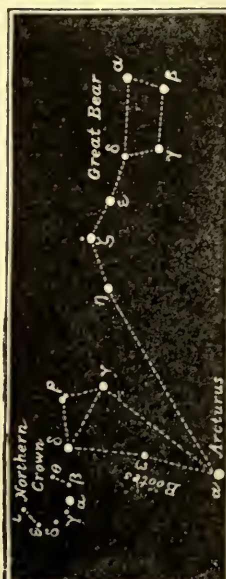


Fig. 18.—Northern Crown, Boötes, Arcturus

his prey, and nothing was more easily done than to petrify the monster by presenting Medusa's head to him, and to liberate the fainting Andromeda. This is a scenic effect from which painting has derived advantage in every sense; there are perhaps as many Andromedas as Ledas, and these are innumerable. It must be owned also that the painter has not often so captivating a subject.

In commemoration of these exploits, and not to give one an advantage over the other, all the family were placed in the heavens, and still remain there. With a little inclination, and knowing pretty well the conven-

tional figures which divide our celestial atlas, we can see under the starry dome Cepheus enthroned, crown on head and sceptre in hand; at his side his wife Cassiopea, seated on a chair ornamented with palms; a little farther on Andromeda, chained to a rock in the midst of an abyss; an immense fish attacks her on one side; Pegasus flying in the air a little in front; and, lastly, the hero of the piece, Perseus, holding in the right hand a curved sword, and in the left the head with the hideous serpents. This is what the mythological eye may still contemplate at midnight during the beautiful season of summer.

Boötes is seen above the Virgin on the zodiacal map. He was called Arcas, and was the son of Jupiter and Callisto. He was also called Atlas, who carries the world, because, formerly, his head was close to the pole. As the Pleiades rise when Boötes sets, it has also been said that they were his daughters. In its vicinity shines like golden rain Berenice's Hair. It will be remembered that 246 years before Christ, Queen Berenice, who made a vow to cut off her hair if Ptolemy Euergetes, her husband, returned victorious, consecrated it to the gods in the temple of Venus, after the victory of the prince. Her husband was very displeased with this unlucky idea, and it was feared that he would not be able to calm his passion, the more so as the queen's hair was stolen the following night; but the astronomer Conon assured him that the regretted hair had been transported to the sky by order of Venus, and actually shone as a constellation.

The Hunting Dogs, or Greyhounds, are not distinguished by any remarkable star, but they possess the most beautiful nebula in the sky: that which I have before described and pictured (p. 6). It is situated in the left ear of Asterion, the northern Hunting Dog. As this left ear touches the tail of the Great Bear, it is easy to find it under the last star of the tail. To discern its form a good telescope is required. This is the nebula which resembles the Milky Way at a distance, and which was for some time considered as a globular cluster surrounded with a ring, until the day when Lord Rosse's great telescope showed it as the most magnificent spiral nebula in the heavens.

III.

THE ZODIAC.

It is known that the Sun in its apparent path above our heads follows a regular and permanent course; that each year, at the same periods, it passes at the same height in the sky, and that it is not so high in the month of December as in the month of June; the path it pursues is not less regular on that account, as it rises and falls in its circuit, and at the same periods it always returns to the same points in the heavens. It is also known that the stars remain perpetually around the Earth, and if they disappear in the morning, to shine again in the evening, it is only because the daylight effaces them. Now, the term *zodiac* is given to the starry zone through which the Sun passes during the entire course of the year. This word comes from *ζώδιον, animal,* an etymology taken from the character of the figures traced on this band of stars. Animals, indeed, predominate in these figures. The entire circumference of the heavens has been divided into twelve parts, which have been named the twelve signs of the zodiac, and our forefathers called them the "houses of the Sun," and again "the monthly residences of Apollo," because the Sun visits one each month, and returns each spring to the commencement of the zodiacal cortege. Two Latin verses give these twelve signs in the order in which the Sun crosses them:

"Sunt: Ariès, Taurus, Gemini, Cancer, Leo, Virgo,
Libraque, Scorpius, Arcitenens, Caper, Amphora, Pisces."

Or rather in English: the Ram ♈, the Bull ♉, the Twins ♊, the Crab ♋, the Lion ♑, the Virgin ♏, the Scales ♎, the Scorpion ♍, the Archer ♐, the He-goat ♄, Aquarius ♒, and the Fishes ♓. The signs placed by these names are the primitive indications which bring them to mind: ♈ represents the horns of a ram; ♉ the head of a bull; ♒ is a stream of water.

If we have now become acquainted with our northern heavens, if its most important stars are sufficiently marked in our mind and their reciprocal relations with each other, we need no longer fear confusion, and it will be easy to recognize the zodiacal constellations. We must note especially that they all belong to one zone, to one belt of the sky, which may serve us as a line of division between the north and south. An easy method of finding this zone in a fine starry night, and to avoid useless search, is to take the Pole Star as the centre of a large circle, and to describe this circle by taking a radius equal to the half of the sky. The line thus described will extend beyond the zenith to the south, and will descend below the horizon to the north; it will mark therefore the celestial equator. Now the ecliptic, on the meridian line of the zodiac, is slightly inclined to the equator, but it only goes beyond it a little, so that our circle will give us, with sufficient exactitude, the line toward which we must look for our constellations.

These summary indications once given, the first signs will be easy to find. To have a complete and lasting knowledge of them, it is necessary to follow the description I am going to give on the accompanying maps, and afterward in the evening to study the originals directly, of which the maps are only copies. These same maps will again serve us, in the following chapter, in studying the southern constellations visible in England.

The Ram is situated between Andromeda and the Pleiades, which we already know. By drawing a line from Andromeda to this

group of stars, the head of the Ram is traversed, formed by two stars of the third magnitude, arranged in a north-east direction. The Ram is the first sign of the zodiac, because, at the time when this principal part of the celestial sphere was established, the Sun entered this sign at the spring equinox. In the fable, it represents the Ram with the golden fleece of the Argonaut expedition, because at the moment when the Sun rises in this sign, guarded by a monster (the Whale) and by a Bull which vomits flames, the constellation Ophiuchus or Jason, comes out in the evening at the same point, and thus subjugates the vanished Ram. The Ram was also the symbol of Spring and the opening of the year. These two causes were indicated by the translator of Plutarch. The Bull comes afterward. We go from west to east. We shall easily recognize it by the group of the Pleiades which sparkle on its shoulder, by that of the Hyades which glimmer on its forehead, and by the magnificent star which marks it right eye, the star Aldebaran, α, of the first magnitude. It is, moreover, situated just above the splendid constellation of Orion, which we shall meet again and make acquaintance with soon ; Aldebaran shines along the line of the Belt to the north-west. (To follow our map.)

The Pleiades, which are seen trembling at the north-west of Aldebaran, are a group of about 80 stars, resolved by the telescope.

The ancients counted in the Pleiades seven stars more brilliant than the ground sprinkled with golden dust. At the present time only six can be counted with the naked eye, which are called, Alcyone or η in the neck of the Bull of the third magnitude ; Electra and Atlas, of the fourth ; Merope, Maïa, and Taygeta, of the fifth. If we are to believe

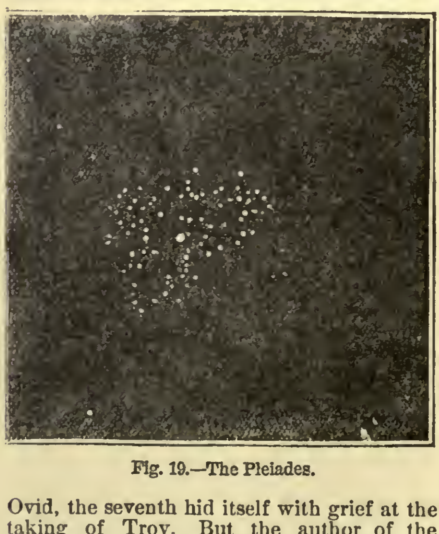


Fig. 19.—The Pleiades.

Ovid, the seventh hid itself with grief at the taking of Troy. But the author of the "Metamorphoses" suspected nothing of the distance of stars and the length of passage of the rays in reaching us. If even one of the Pleiades hid itself at the taking of Troy, Ovid would still have seen it in the place which it formerly occupied, and perhaps even now we should have still seen it there. The Hyades form a V with Aldebaran, which occupies the southern extremity. Like the Pleiades, they announce rain ; their name signifies *to rain*, and that of their companions signifies *navigator*.

The Twins are easy to recognize to the east of the preceding stars, their heads being formed of two beautiful stars, Castor and Pollux. We shall also reach them by a diagonal, crossing the Great Bear. Again, Castor, of the first magnitude, forms a triangle with the Goat and Aldebaran. Therefore, nothing is more easily found. Descending toward the Bull, eight or ten stars terminate the constellation, and lower down, Procyon is met with, a star of the second magnitude. This region, marked with Orion, Sirius, the Twins, the Goat, Aldebaran, and the Pleiades, is the most magnificent region of the celestial sphere. It is toward the end of autumn that it shines in our hemisphere in the evening. The Twins are, in the fable, Castor and Pollux, sons of Jupiter, celebrated for their indissoluble friendship, for which they were rewarded by immortality. The Greeks also gave the name of Castor and Pollux to those lights which appear round vessels after storms, electrical phenomena now called the fires of Saint Elmo.

The Crab or Cancer may be distinguished at the bottom of the line of Castor and Pollux, in five stars of the fourth or fifth magnitude. It is the least important body of the zodiac.

The Lion is a large trapezium of four beautiful stars, situated to the east of the Twins. They may readily be found by continuing in the opposite direction the line, from α, β of the Great Bear, which served us to find the Pole Star. The most brilliant of these stars, α, is of the first magnitude and is called Regulus, the heart of the Lion ; the three others, β, γ, and δ are of the second magnitude. The Sun enters the Lion at the summer solstice, and causes it to disappear by covering it with his fires ; this is the victory of Hercules over the Lion of Nemea. It was also for the same cause the symbol of strength and power. Being the abode of the Sun during the month of July, it was again the sign of burning heats and of plagues which they sometimes brought with them. In the eyes of astrologers of the middle ages, this was its terrible aspect. The Virgin comes after the Lion, still to the east, as will be seen on the map. If we again use the very accommodating constellation which has until now been so useful to us, we must continue toward the south the great diagonal α, γ from the square of the Great Bear, and we shall meet with a beautiful star of the first magnitude placed just to the left of our figure ; this is the Virgin's ear of corn, or Spica, a star known from all antiquity. Now that we can distinguish Arcturus, or Boötes, and α of the Lion, we may also remark that

these two stars and Spica form together an equilateral triangle. The star β, situated in the right arm of the Virgin, is called the Vintager. It forms a triangle with β of the Lion and Berenice's Hair.

Emblem of justice and law, the Virgin represents Themis, with the scales at her feet. Why has she wings? Perhaps because Justice, formerly on the earth, abandoned it for heaven. She is also Astrea, daughter of Jupiter, and Themis, men's crimes having forced her to return to heaven at the end of the golden age. She has the privliege of representing a great number of persons; the entire list would be too long, the following being only a few of them: Ceres, symbol of harvests; Diana of Ephesus; Isis of Egypt, goddess of Syria; Atergatis or Fortune; Cybele drawn by lions; Minerva, mother of Bacchus; Medusa; Erigona, daughter of the Cow-herd; lastly, in the time of Virgil, she was the Sybil, who, with branch in hand, descended to the infernal regions. With so large a choice, she seems to have preferred the title of Daughter of Justice, exiled to the celestial regions by man's crimes.

The Scales is the seventh sign of the zodiac. To the east of Spica, two stars of the second magnitude are seen; these are α and β, marking the top of the Scales. With two other less brilliant stars, they form an oblique square on the ecliptic. Two thousand years ago, the Sun passed them at the autumnal equinox, and this is the origin of that sign which "equals the day to night, work to sleep."

The Scorpion, with its heart marked by the brilliant Antares, a star of the first magnitude, is easily recognized. It is not that the form can be distinguished; for this form is not better sketched out by the stars which compose it, than the preceding figures, the Scales, the Virgin, etc., have been. But it is well understood that, when we speak of recognizing a constellation, we refer simply to the groups of stars which bear its name, and not to its mythological figure. Antares, α of the Scorpion, is on the continuation of the line which would join Regulus (α of the Lion) to Spica; these are three stars of the first magnitude placed in a straight line, in a west-east direction. Antares also forms with Lyra and Arcturus a large isosceles triangle, the latter star being at the vertex. The second star of the Scorpion, β, of the second magnitude, marks the head. A string of stars of the third magnitude traces out the curved tail.

The Scales and Scorpion only formed one sign with the Latins before Augustus: the Scales were then the claws of the Scorpion. As Augustus was born on the 23d of September, flattery leagued itself with astrology to celebrate the happiness promised to the Earth by the birth of this emperor; the Scales, which the Egyptians had formerly instituted in the original sphere, were replaced in the heavens as a symbol of Justice.

The verses of the Eneid may now be easily interpreted. As a sign of misfortune and fear, the Scorpion was cursed among all the constellations. It was said, especially, that it had an invincible hatred toward Orion, because this figure sets when the former rises, and *vice versâ*. It was not only the terror of the stars, but also the terror of the Sun himself, that Ovid has described it to us.

Sagittarius (the Archer), forming an oblique trapezium, is a little to the east of Antares, still following the direction of the ecliptic. It only contains stars of the third and less magnitudes; α, δ, γ, form the arrow; the last, γ, is called Nushaba by the Arabs. The star π marks the head.

Capricornus (the He-goat) is not rich in bright stars. Those which parkle on his forehead, α and β, are the only ones which can be distinguished by the naked eye. They are on the continuation of the line which passes from Lyra to the Eagle. The region of the Zodiac which we are now visiting is the poorest in the heavens; it presents a striking contrast with the opposite region, where we admired Aldebaran, Castor and Pollux, the Goat, etc.

Above Capricornus shines Altair, or α of the Eagle: the stars of Antinoüs form a trapezium on the path from Capricornus to the Eagle. In some authors this sign represents the goat Amalthea, which nursed Jupiter on Mount Ida, and received a place in heaven as a reward. According to others, it represents the return of the Sun to the winter solstice through the gates of the tropics. Again according to others, it was a he-goat which was brought up with the king of the gods, and which discovered and sounded the marine trumpet, and produced fear among the Titans in their war with Olympus. The frightened gods hid themselves in the forms of different animals; Apollo changed into a crane, Mercury into an ibis, Diana into a cat. Such a metamorphosis was never seen. Lastly, Pan into Capricornus, having a goat's body and the tail of a fish. He appeared, also, to wish to steal away with the giants who scaled heaven.

Aquarius forms with his three tertiary stars a very obtuse triangle. The base is prolonged in a string of stars from the side of Capricornus and toward the left to the Urn. Thence begins a sinuous line of very small stars descending to the horizon. This is the water poured out by Aquarius. Aquarius appears to personify Ganymede, who was raised by Jupiter's eagle to serve as cupbearer to the gods after the fall of Hebe.

The Fishes, the last sign of the Zodiac, lie to the south of Andromeda and Pegasus. The northern fish is that which wished to devour Andromeda; the western fish advances in the square of Pegasus; they are bound together by a band. Not so apparent as the preceding, this constellation is composed of two rows of very small stars, which start from α of the third magnitude, the knot of the band, and diverge one toward α of Andromeda, the other toward α of Aquarius. Ovid tells how Venus and Love, wishing to steal away at the pursuit of the giants,

crossed the Euphrates on two fishes, which were for this placed in heaven. It is related that two fishes having found an egg of a very beautiful shape, drew it to shore, that a dove sat on it, and Venus came forth. It was from this time that the Syrians abstained from feeding themselves on fish. This sign is the last abode of the Sun before the renewing of the year, in the month of February; this was the time of the inundation of Egypt and that of fishing with us. It closes the circle of the zodiacal constellations.

If our descriptions have been well followed on our map, the zodiacal constellations will be as well known as those of the north. Little now remains before we become familiar with the whole heavens, yet there is an indispensable complement to the preceding. The circumpolar stars are always visible above the London horizon; at any time of the year that we wish to observe them, they may always be found, either above, below, or on one side or the other of the Pole Star, which has served us to find them, and always preserving the same relation one with the other. The zodiacal stars do not resemble them in this point of view; for they are sometimes above the horizon and sometimes below it. We must, therefore, know at what time they are visible. For this it will be sufficient to remember the constellation which is at the centre of the heavens at nine o'clock in the evening, on the first day of every month, that, for instance, which at that hour crosses a line drawn from the Pole Star, from north to south, dividing the sky into two parts. This line is called the meridian, and all our figures cross it, passing from east to west. Marking each of the constellations which pass at the indicated hour, we thus give the centre of the visible constellations. Looking for the northern ones at the north; to its left those which precede the indicated constellation in the order of the signs; to its right those which follow it, all will be found without difficulty. On the first of January the Bull passes the meridian. Notice Aldebaran and the Pleiades. 1st of February: the Twins have not yet reached there; they are seen a little to the right. 1st of March: Castor and Pollux have passed, Procyon at the south; the little stars of the Crab to the right. 1st of April: the Lion, Regulus. 1st of May: β of the Lion, Berenice's Hair. 1st of June: Spica of the Virgin, Arcturus. 1st of July: the Scales, the Scorpion. 1st of August: Antares, Ophiuchus. 1st of September: Sagittarius, the Eagle. 1st of October: Capricornus, Aquarius. 1st of November: the Fishes, Algenib or ψ of Pegasus. 1st of December: the Ram.

Our general revision of the starry heavens ought now to be completed by the stars of the Southern sky.

I have only given a rapid summary of the mythological explanation of the signs of the Zodiac; the uncertainty which reigns over their origin has allowed many to be suggested. I shall only recount here, that which supposed them to be the twelve labors of Hercules, a suggestion which does not lack a certain ingenuity. Hercules would be no other than the Sun himself considered in his attributes relatively to the different times of the year. Francœur, in his *Uranographie*, according to Lalande and the philosopher Dupuis, charged himself with supporting this curious system.

The entrance of the Sun into the solstitial Lion which he made to disappear by covering it with his fires, is the victory over the Lion of Nemea. In proportion as the Sun advances he crosses Cancer, the Lion, and the Virgin; the different parts of the Hydra are eclipsed by turn; first the head, then the body, and lastly the tail; but then the head reappears in its heliacal rising. This is the triumph over the Hydra rising again from the Lake Lerna, which Hercules burned, after having crushed the Crab which aided it. The Sun crossing the Scales at the time of the vintages covers the Centaur with his fires. The fable states that the Centaur Chiron, having received Hercules, taught him the art of making wine. It adds that, in a drunken dispute, the people of the Centaurs wished to kill Hercules' host, which forced the hero to fight with them; this appears to relate to the setting of Sagittarius in the evening. Lastly, in hunting, he conquered a monster, called the wild boar of Erymanthus, which was believed to refer to the rising of the Great Bear in the evening.

Cassiopea, who is represented also by a hind, in the morning sets in the waves when the Sun is in Scorpion, which happens at the autumnal equinox; it is this hind with golden horns which, in spite of its wonderful velocity, Hercules tired out in a race, and caught at the water's edge when she reposed.

At the rising of the Sun in Sagittarius, the Eagle, Lyra (or the Vulture), and the Swan, situated in the Milky Way, disappear at once; these are the birds of the Lake Stymphalis, driven out of Arcadia by Hercules, whose arrow is placed among them. Capricornus, or the celestial He-goat, is bathed in front by the water of Aquarius; these are the stables of Augias cleansed by a river passing through them.

The Sun in Aquarius, or the winter solstice, was near Pegasus; in the evening the Vulture was seen to set, while the Bull passed the meridian; it was said that Hercules, on his arrival in Elis, to fight the Bull of Crete and the Vulture of Prometheus, mounted the horse Arion and instituted the Olympic Games, which are celebrated at full moon of the summer solstice; the moon is then exactly in Aquarius, that is to say, in the region opposite to the Lion. The carrying off of the mares of Diomedes, son of Aristes, relates to the heliacal rising of Pegasus and the Little Horse, the Sun being in the Fishes. These two Horses are placed above Aquarius, which is Aristes.

Hercules afterward starts for the conquest of the Golden Fleece, Aquarius and Serpen-

tarius rise in the evening, while at the same time the Ram, Cassiopea, Andromeda, the Pleiades, and Pegasus set. Hence the victory of Hercules over Hippolyte, queen of the Amazons, whose belt (Mirach) shines with a bright light. Many of these warriors had the names of the Pleiades.

At the rising of the Bull, the Cow-herd (Boötes) sets, and the Great Bear (the oxen of Icarus) rises. This is the defeat of Geryon and the carrying off of his oxen. Hercules kills Busiris, persecutor of the Atlantides: the fable which alludes to Orion pursuing the Hyades, and who is then hidden in the solar beams. The return of spring is moreover explained by the destruction of the venomous reptiles of Crete and by the defeat of the brigand Cacus; that of the river Achelaüs, changed into a bull, relates to Eridanus, which is situated below.

After having founded Thebes in Egypt, Hercules went to the infernal regions, delivered Theseus and carried off Cerberus. The Sun has arrived in the northern hemisphere; the Great Dog, whose heliacal setting took place in the preceding sign, is now absorbed in the Sun's brightness; he is taken from the infernal regions, and brought to the light. The river of Aquarius, which rises in the evening with the Swan, when the Sun has traversed the constellation of the Twins, is Cycnus conquered at the borders of Penea.

The Northern Dragon and Cepheus, or the garden of Hesperides, rise at the setting of the Sun under Cancer; hence the voyage of Hercules in Hesperia. The time of the heliacal rising of the constellation of Hercules is in autumn; the apples of the Hesperides are an allusion to this season.

Returned to the summer solstice, the Sun recommences its revolution: this is the apotheosis of Hercules. Fable relates that Dejanira, seeking for a love-potion to keep her husband, sent him a shirt soaked in the blood of the Centaur Nessus. Hercules put it on to sacrifice to the gods, and to ask of them the immortality promised for his exploits; but, devoured by the poison in the garment, the hero burned himself on the funeral pile. This is the sense of this fable. The Sun has entered the Lion and rises, while the constellations Hercules and Aquarius are about to set. The Centaur sets a little after the Lion; this one then causes Hercules to die, and Aquarius, Ganymede, is carried off to pour out nectar to the gods, in the place of Hebe, given to the hero. The reconciliation of Hercules and Juno relates to Aquarius, who is dedicated to the goddess.

Hercules lived 52 years, had 52 wives, and accorded the Nemean honors to 360 of his companions who died for him: this alludes to the 52 weeks of the year and to the 360 degrees of the Zodiac. The Pillars of Hercules were the western limits of the known Earth, where the Sun seemed each day to set in the sea.

However vague many of the interpretations just put forth may seem to be, adds Francœur, there are some so remarkable that they cannot be supposed to be altogether the effect of chance: thus Hercules was not a hero whose good actions excited men to erect altars to him; but the Sun, considered in his attributes relative to the different epochs of the year; an opinion agreeing with the most revered testimonies of the ancients.

IV.

THE SOUTHERN CONSTELLATIONS.

"A TOUT seigneur tout honneur." Orion is the most beautiful constellation; we must not pass it without doing homage to it, and the best way of rendering homage to persons of worth is to learn how to understand them.

Let us observe our map: below the Bull and the Twins, to the south of the Zodiac, you will notice this giant who raises his club toward the forehead of the Bull. Seven bright stars are distinguished; two of them,

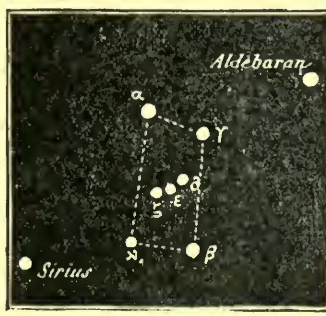


Fig. 20.—Orion, Aldebaran, Sirius.

α and β, are of the first magnitude; the other five are of the second; α and γ mark the shoulders, χ the right knee, β the left foot; δ, ϵ, ζ mark the belt; below this line is a luminous train of three stars close together, this is the Sword. Between the western shoulder, γ, and the Bull, is seen the Shield composed of a curved string of little stars. The head is marked by a little star, λ of the fourth magnitude; μ and ν denote the raised arm.

For more clearness, we give the arrangement of the principal stars of this magnificent asterism.

Orion is on the continuation of the line which joins the Pole Star to Capella. The four stars, α, γ, β, κ, occupy the angles of a great quadrilateral; the three others δ, ϵ, ζ, are close together in an oblique line in the middle of this quadrilateral; α, in the north-east angle, is called Betelgeuse (not Betelgeuse, as generally printed), β, of the south-west angle, is called Rigel.

The line of the Belt, prolonged on both sides, passes on the north-west by the star Aldebaran in the eye of the Bull, which we already know, and on the south-east by Sir-

ius, the most beautiful star in the heavens, with which we shall soon occupy ourselves. It is during fine winter nights that this constellation shines over our heads. No other season is so magnificently constellated as the winter months. While nature deprives us of certain enjoyments on the one hand, it presents us with others no less precious. The wonders of the heavens present themselves to amateurs from the Bull and Orion at the east as far as the Virgin and Boötes at the west; of eighteen stars of the first magnitude, which may be counted in the whole extent of the firmament, a dozen are visible at nine o'clock in the evening, not counting many beautiful stars of the second order and the remarkable nebulæ and heavenly objects very worthy of the attention of mortals. These twelve stars are: Sirius, Procyon, Capella, Aldebaran, Spica, the heart of the Hydra, Rigel, Betelgeuse, Castor and Pollux, Regulus, and β of the Lion.

Thus it is that nature establishes everywhere harmonious compensation, and while it darkens our short and frosty winter days, it gives us long nights enriched with the wealthiest creations of the heavens.

The constellation of Orion is not only the richest in bright stars, but it conceals also treasures for the initiated which no other can present. We might almost call it the California of the heavens. We will enumerate its riches, and shall then find greater delight in contemplating it in the heavens.

Let us speak first of its nebula, situated below the second star of the Belt. The first time that Huygens, its discoverer, admired this cosmical beauty, in 1656, he was sufficiently astonished to say, that it seemed an opening in the sky which threw light on a more brilliant region. "Astronomers," he states, "have counted in the sword of Orion three stars very near each other. In 1656, I accidentally observed that, in place of one of these stars which occupy the centre of the group, there was a dozen of them, a result which is not rare to obtain with telescopes. Of these stars there were three which, like the first, nearly touched each other, and four others seemed to shine through a cloud in such a manner that the space which surrounded them appeared much more luminous than the rest."

Since that period this nebula has been studied with a kind of predilection; it has been minutely examined and the different regions of its cluster have been studied and described in all their details. In proportion as the instruments have become more powerful, the stars, which constellate it, appear more numerous, which has happened in all telescopic observations of nebulæ; and, while in early days it was asked with great uncertainty if there was only a phosphorescent cloud, a vaporous mass—astronomers afterward arrived at the conviction that it was formed of an immense number of heaped-up suns, and then again that it was a true cosmical cloud. At the centre is seen a brighter part of singular form; Sir J. Herschel compared it to the head of a monstrous animal, with gaping mouth, the nose being prolonged like the trunk of an elephant.

It occupies a large space in the sky, its apparent dimension being equal to that of the lunar disk. When we think of the distance which separates us from this agglomeration, we are dismayed at the real extent which it embraces in the midst of the boundless void.

But the strangest phenomena which are attached to this nebula are the changes which are observed in it. The drawings which are now taken differ from those which were taken half a century ago. Again this year (1867), there has been noticed in England an indication of brightness, through a dark portion, which did not exist ten years ago. Astronomers agree that there is no possible delusion in some of these observations, and that this distant agglomeration is the seat of formidable disturbances.

"The general impression that I have received from these observations," said the director of the Russian Observatory not long ago, "is that the central part of the nebula is in a state of continual agitation, like the surface of the sea."

Orion possesses many other riches. The star of the left foot, Rigel, is one of the most beautiful double stars. (We shall soon commence this chapter of Sidereal Astronomy.) This double star is composed of a white and a blue sun. In calm and clear nights which we sometimes have in the winter, it appeared to me sometimes that the reflection of the blue star tinted the brightness of the white sufficiently to cause this to seem slightly tinted with blue, especially when it is compared with the golden points which sprinkle the surrounding sky.

Two other binary systems are met with in the two stars at the extremities of the Belt. The first to the right is composed of a white and a purple sun; the second, of a yellow and a blue sun. Thus here are three systems of the most dissimilar worlds united in the same constellation. In each of these systems two suns instead of one; not only two suns like ours, but two differently colored suns; in the planets which belong to the first, a white and a blue body dispute the empire of the day with each other, giving rise, by the numberless combinations of their heat, light, and electrical power, to a variety of actions incomparable and unimaginable by us, who are devoted to one sun. In the planets which belong to the second, it is a purple sun which diversifies the white light of its compeer. In that of the third the number of colors is essentially different from ours, as there is no white light the generator of every tint: and presents an unknown series of shades the result of the combinations of gold and sapphire. These planets are doubtless green, and the color of the objects on their surface must probably oscillate round this medium either as yellow or blue.

But this wealth of stellar systems does not yet constitute all the patrimony of this beau-

tiful constellation of Orion. It contains, besides, the most complex of multiple systems which have ever been met with in the heavens. In the nebula of which I have just spoken an extraordinary star is met with, the star marked θ in the catalogues, a little below the Sword. This star, divided by the telescope, presents to our admiration six suns collected in one point of the heavens. Four principal stars of the fourth, sixth, and seventh magnitudes are arranged at the four angles of a trapezium ; the two stars at the base have each a very feeble companion. That these six stars form in reality a physical system, and that they are connected together, like the binary systems, by the law of attraction, is a statement I do not wish to affirm. It may be that this is only an optical effect—that these six stars are in reality completely independent of each other, situated at immense distances and depths, but, being on the line of sight very near together, they appear to us collected on one plane. Nevertheless, there are probabilities in favor of the opinion which considers this sextuple star as an actual system, especially when we see that the movement belonging to the principal star is shared by the five others.

Another star in Orion, the twenty-third, is equally remarkable, being double, and instead of having its principal white and its small one blue, as in the generality of cases, it is the contrary that is noticed.

This is a great deal for one constellation ; but for this beautiful and ancient figure, about which Job sang three thousand years ago, I have a sympathy for which I cannot and will not defend myself. Between the Pleiades and the beautiful Sirius, it presents to me a magnificent celestial region, enriched with varied worlds, which makes one dream of distant life. Between ourselves, I read an astrological treatise of the middle ages ; its title was "Flamma Orionis." Since that time this name is dear to me : I love it ! Now, you know what happiness it is to lovers to speak continually of the object of their devotions. Following its course, like the Sun, and the planets, and zodiacal constellations, the moon sometimes passes near Orion. It then hides the stars over which its path conducts it.

In the fable, Orion, the handsomest man of his time, was of such high stature that, when he walked on the bottom of the sea, his head exceeded the height of the waves ; which means that this constellation is half beneath the equator and half above.

I have forgotten to add, that the three oblique stars which form his belt have been named the Three Magi Kings, Jacob's staff, and that in France we simply distinguish them under the name of the Rake.

To the south-east of Orion, on the line of the Three Kings, shines the most magnificent of all stars, Sirius, or a of the constellation of the Great Dog. This star of the first magnitude marks the upper eastern angle of a great quadrilateral, whose base reaches the London horizon, and is adjacent to a triangle. The stars of the quadrilateral and the triangle are all of the second magnitude. This constellation rises in the evening, at the end of November, passes the meridian at the end of January, and sets at the end of March.

Sirius being the most brilliant star of the heavens, and astronomers daring to attempt operations relative to the study of the distances of stars, this attracted their attention. After long and minute study, they succeeded in determining its distance ; 1,375,000 times the distance of the Sun. To traverse the distance from the Earth to this star, light takes nearly twenty-two years. Hence, it follows that, when we see it, it is not the Sirius of to-day which is before our eyes, but rather the Sirius of twenty-two years ago ; the ray of light which reaches our eye now left Sirius during the year 1848.

The name we now give to a of the Great Dog formerly belonged to the whole constellation, and not a single Egyptian monument is found where this figure is indicated without its representing Sirius, a name derived from Osiris, the Sun. At the time the constellation was formed, the summer solstice happened when the Sun crossed Capricornus ; the rising of Sirius announced to Egypt the time of the overflowing of the Nile, and like a faithful dog warned men to be on their guard. The *rôle* of Sirius did not stop here. The civil year of the Egyptians being exactly 365 days, and their kings swearing never to allow the intercalation of supplementary days, this year advanced a day every four years on the solar year, and again coincided with it at the end of 365 times four years—in 1460 years ; but during this time the civil periods, agricultural labors, fêtes, and the different parts of the calendar, could not be fixed by unchangeable dates. They therefore chose a sign in the heavens which announced the period of the solstice ; the rising of Sirius in the morning, which was then called Sothis, announced the desired epoch. The heliacal (solar) rising of this star only happened on the same day after 1461 years.

Since those ancient days, a movement of the Earth which slowly modifies the path of the Sun among the constellations, which is called "the precession of the equinoxes," has deprived Sirius of its faculty of predicting the inundation and the solstice ; its heliacal rising happens in Egypt now on the 10th of August instead of the 20th of June. But at the beginning of our era, it took place in July, in the midst of the great heats and the diseases they engender. Hence, this constellation was accused of a malignant influence, as may be seen in Sophocles and a hundred other more modern authors ; it gives fever to men and madness to dogs. The term dog days is derived from this. In order to conciliate Sirius, they raised altars on which were sacrificed the quail and the goat. They dreaded the star of the south.

Sirius, or the Dog-star, was also called the Dog of Procris, wife of Cephalus, who

pierced her with an arrow shot accidentally, as Ovid relates at great length.

Sirius has a long and good reputation as a dog. After all the services which he had rendered to the Egyptians, Jupiter charged him with the care of his dear Europa; after the carrying off, he passed through the hands of Minos, Procris, Cephalus, and Aurora. Well-known authors even think that, in spite of all that precedes, he was Cerberus, the dog with three heads; their opinion is supported by this coincidence, that the Great Dog guards at the equator the lower hemisphere of the Egyptians, in the same manner as Cerberus watched the region of Tartarus. It is seen that this dog claims a very ancient nobility. No heraldic title can boast of such antiquity.

The Little Dog, or Procyon, which we have already seen on our zodiacal maps, is above Sirius and below the twins, Castor and Pollux, to the east of Orion. No bright star distinguishes it, unless it be α. From a mythological point of view, it shares with the Great Dog most of the fables attributed to the latter.

The Hydra is a long constellation which occupies that quarter of the horizon under the Crab, Lion, and Virgin. The head, formed by four stars of the fourth magnitude, is to the left of Procyon, on a line drawn by this star and Betelgeuse. The western side of the great trapezium of the Lion, like the line joining Castor and Pollux, is directed to α, of the second magnitude: it is the heart of the Hydra. On the back of the Hydra, stars of the second order may be noticed, the Raven and the Cup. Being like a river in its meanderings, the Hydra has been regarded as an inhabitant of the Nile and its representative. As the ship Argo is not far from here, some have even gone so far as to explain by certain aspects the deluge of Deucalion, who escapes in a vessel, and who, forty days after, makes certain that the waters have retired by sending forth a raven.

Eridanus, the Whale, the Southern Fish, and the Centaur are the only important constellations we still have to describe. They will be found in the order indicated, to the right of Orion. Eridanus is a river composed of a series of stars of the third and fourth magnitude, which descends and winds from Orion's left foot to Rigel, being lost under the horizon. After having followed long windings, invisible to us, it is terminated by a beautiful star of the first magnitude, α or Achernar. This was the river into which Phaëton, who awkwardly conducted the car of the Sun, fell: it was placed in heaven to console Apollo for the loss of his son.

Below the Ram, a star of the second magnitude is met with, which forms an equilateral triangle with the Ram and the Pleiades: this is α, or the jawbone of the Whale; α, μ, ξ and γ form a parallelogram—this is the head. The base, α, γ, is prolonged to a star of the third magnitude, δ, and to a star of the Neck marked o. This star is one of the most curious in the heavens; it is called the Marvellous. Miro Ceti. It belongs to the class of variable stars. Sometimes it equals in brightness stars of the first order, at others it becomes completely invisible. Its variations have been watched since the end of the sixteenth century, and it has been noticed that the period of increase and decrease is in the mean 331 days, but always irregular, being sometimes 25 days behind or 25 days in advance. The study of these variable stars will present curious phenomena to us.

The Whale was sent by Neptune to devour Andromeda. I shall not return to the history of this poor princess.

Four stars of the third magnitude form the tail of this cetacean and descend toward Fomalhaut, or α of the Southern Fish, which receives water from Aquarius. This asterism rises very little above the horizon of London.

Lastly, the constellation of the Centaur is situated below Spica of the Virgin. The star θ, of the second magnitude, and the star ι, of the third, mark the head and shoulder: this is the only part of the figure which rises above the horizon of London. The Centaur contains the star nearest to the Earth, α, of the first magnitude. It is also in this constellation that the beautiful regular nebula is found, which we have already admired, the globular cluster Omega of the Centaur. The feet of the latter touch the Southern Cross, formed of four stars of the second magnitude, always hidden below our horizon. A little farther south is the south pole.

V.

THE NUMBER OF THE STARS—THEIR DISTANCES.

In order that the mind may be less confused in the midst of these thousands of sparkling points it has been agreed from the highest antiquity to class the stars according to their apparent brightness, besides the divisions we have just mentioned. We have seen that the brightest stars have been called stars of the first order or magnitude, although this term does not imply anything relative to the actual size or brightness of the stars; those which follow, still in the order of their apparent brightness, have been called stars of the second magnitude; then come those of the third, fourth, and fifth magnitude, according as they appear smaller; lastly, stars of the sixth magnitude are the last stars visible to the naked eye.

The stars of the first magnitude are eighteen in number. In reality, the eighteenth, that is to say, the least brilliant of the series, might as well be inscribed in the first rank of the stars of the second magnitude, and the first of this second series might, in the same way, be added to the stars of the first magnitude. There is nothing in the nature of these separations which necessitates our classification; but as we must stop at one star, and a series is to be made, it has been agreed to make the list of stars of the first magni-

tude as follows:

List of Stars of the First Magnitude in the order of their decreasing brightness.

1. Sirius, or α of the Great Dog.
2. η of Argo (variable star).
3. Canopus, or α of the Vessel.
4. α of the Centaur.
5. Arcturus, or α of the Cowherd (Boötes).
6. Rigel, or β of Orion.
7. Papella, or α of Auriga.
8. Vega, or α of Lyra.
9. Procyon, or α of the Little Dog.
10. Betelgeuse, or α of Orion.
11. Achernar, or α of Eridan.
12. Aldebaran, or α of the Bull.
13. β of the Centaur.
14. α of the Cross.
15. Antares, or α of the Scorpion.
16. Atair, or α of the Eagle.
17. Spica, or α of the Virgin.
18. Fomalhaut, or α of the Southern Fish.

It is generally thought that the brightest are the nearest, and that the stars appear to us smaller the more distant they are from us. Hence it follows that the number of the stars must increase in the inverse ratio of each magnitude: that the stars which form the second series, for instance, being on a more distant, and consequently larger, visual circle than that of the first series, are more numerous: that the third series is richer than the second, and so on. This is precisely what is observed. The stars of the second magnitude number about 55; of the third, 170; of the fourth, 500, etc. The following is, indeed, an easy method of knowing approximately the number of stars of each order. It has been remarked that each class is generally three times more numerous than that which precedes it; so that by multiplying the number of stars which compose any series by three, we have nearly the number of those which compose the following series. By this calculation the number of the stars of the six first magnitudes—in other words, that of the whole of the stars visible to the naked eye—would give a total of about 6000. Generally it is thought that more may be seen; we think we can count them by myriads, by millions: in this as in everything else, we are always given to exaggeration! Yet, in fact, the number of stars visible to the naked eye, in both hemispheres, does not exceed this figure, and even then there are few eyes good enough to see more than 4000 or 5000.

But here, when our feeble sight gives way, the telescope, that giant eye which increases from century to century, piercing the depths of the heavens, constantly discovers new stars. After the sixth magnitude, the first glasses revealed the seventh. Then they reached the eighth, the ninth. It is thus that thousands have increased to tens of thousands, and that tens of thousands have become hundreds of thousands. More perfect instruments have cleared these distances, and have found stars of the tenth and eleventh magnitudes. From this period they began to count by millions. The number of the stars of the twelfth magnitude is 9,556,000; added to the eleven preceding magnitudes, the total exceeds fourteen millions. By the aid of still greater magnifying power, these limits are again surpassed. At the present time, the total number of stars, from the first to the thirteenth magnitude, inclusive, is calculated at 43.000,000. The sky is truly transformed. In the field of the telescope, neither constellations nor divisions are distinguished; but a fine dust shines in the place where the eye, left to its own power, only sees darkness on which stand out two or three stars. In proportion as the wonderful discoveries in optics will increase the visual power, all regions of the sky will be covered with this fine golden sand; and a day will come when the astonished eye, raised toward these unknown depths, will be startled by the accumulation of stars which succeed each other in an endless manner, and will only discover a delicate tissue of light.

What is the extent occupied by these myriads of stars which succeed each other eternally in space? This question has always attracted the attention of astronomers as well as that of simple thinkers; but they were not able to commence any researches relative to its solution until lately, when delicate means have become accessible to us.

The ancients did not form the slightest idea of the distance or nature of the heavenly bodies: they were thought to be emanations from the Earth, rising like the *ignes fatui* over marshy places. This would be a long and curious story, and, like that of all primitive ideas, but little in harmony with the grandeur of creation. To possess the power of measuring the distance of the nearest star, it is necessary to measure the thickness of a hair. A long time elapsed before this was accomplished. I shall give at the end of this chapter an idea of the method employed, in order to succeed in these exact determinations; we will first satisfy our curiosity, and learn at what distance the nearest stars are from us.

The nearest star is in the southern constellation of the Centaur; it is the star a. According to the most recent researches, it is distant from us 211,300 times the distance from here to the Sun. A few years ago, it was believed to be farther, but more exact determinations have definitely established that it is not beyond the distance just mentioned.

It is very difficult, if not impossible, to figure to one's self such distances, and to comprehend them, it is necessary for our mind to associate with the idea of space the idea of time; to travel in some way along this line, and to estimate its length by time. For small distances, we do the same on the Earth. If, for example, it is said that it is 310 miles from Paris to Strasburg, we with difficulty figure this distance at first sight; but by associating the idea of the time necessary to pass through it with a given velocity, by learning that an express train going at

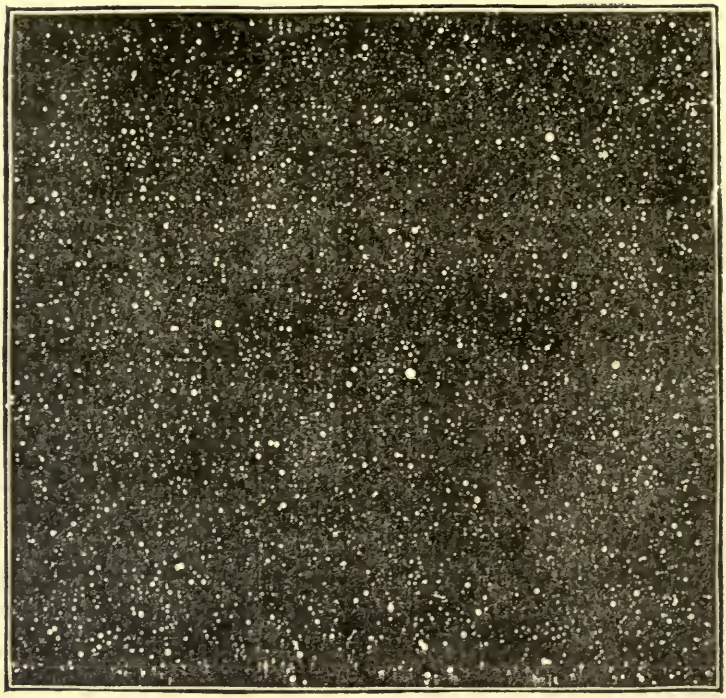


Fig. 21.—A part of the constellation of the Swan, as seen through the telescope.

the rate of 44 miles per hour, arrives there in seven hours, we represent to ourselves the road traversed. This method, useful for terrestrial distances, is necessary for celestial ones: we shall also measure space by time; only, instead of the velocity of a train, we shall take that of light, which travels at the rate of 186,000 miles per second.

Well, to traverse the distance which separates us from our neighbor *a* of the Centaur, our courier takes three years and eight months. If the mind wishes to follow it, it must not jump with the twinkling of an eye from the departure to the arrival, otherwise it would no longer have the slightest idea of the distance; it is necessary to represent to itself the direct path of the luminous ray, and not associate itself with this path, which it must imagine to travel 186,000 miles during the first second of route, dating from its departure; then 186,000 miles for the second second, which makes 372,000 miles; then again 186,000 miles during the third, and so on without stopping for three years and eight months.

If we give ourselves this trouble, it will enable us to understand the enormous value of the number; otherwise, as it exceeds every number which the mind is accustomed to use, it will not have any meaning and will remain uncomprehended.

Our nearest star is *a* of the Centaur. The one whose distance places it immediately after is a star situated in another region of the sky, in the constellation of the Swan. This is our second nearest; which does not prevent it being nearly three times more distant from us than the first. The distances of ten stars have been calculated. The following are the nearest: The first column of numbers represents the number of radii of the terrestrial orbit (distance from the Earth to the Sun) which must be laid out in line, one from the other, to reach the star; the second column indicates the number of years light takes to traverse the distance:

α of the Centaur	211,330	3 years 8 months
α of the Swan	550,920	9½ years.
Vega, α of Lyra	1,330,700	21 "
Sirius, α of the Great Dog	1,375,000	22 "
α of the Great Bear ..	1,550,800	25 "
Arcturus, α of Boötes..	1,622,800	26 "
Pole Star	3,078,600	50 "
The Goat, α of Auriga.	4,484,000	72 "

These are the nearest stars. Most of the stars whose distances have been calculated are some of the brightest in the heavens, and are among those of the first and second magnitude. It may be asked if it be possible, by comparison, to determine the probable distance of the regions where the least magnitudes shine. This is a curious question, which Arago tried to solve and on which he

reasoned as follows:

We take, for instance, from the foregoing list a mean star of the first magnitude, not Sirius, which exceeds all the others by its brilliancy, but Arcturus or Vega; we ask ourselves to what distance must this star be transported in order that it may diminish in apparent brightness to the fourth magnitude, and we see that it is necessary to transport it to a distance four times greater than its present distance; by withdrawing it to eight times the original distance, it would become from the fifth to the sixth order: in the mean, a star of the first magnitude, transported to twelve times its actual distance, would still be visible to the naked eye, and its light would not fall below the sixth magnitude.

William Herschel tried to extend the scale of visibility which he had formed for the naked eye to telescopic observations. He prepared a series of telescopes of gradually increasing power, and for the subject of his observations he took the nebula of Perseus. There the eye could not distinguish any star. If there were any, they were necessarily more feeble than the stars of the first magnitude would be, transported to twelve times their actual distance; the small instrument showed a great number. Let us admit that, in this great number, there are, which is probable, as bright stars as Arcturus, Vega, etc., these stars, in order to become just visible after their intensity was quadrupled, must be twice as far as the last stars visible to the naked eye, that is to say, twenty-four times farther than Arcturus, Vega, etc.

The second instrument, which increased the light in the proportion of nine to one, and brought the objects three times nearer, discovered stars the traces of which were not to be found in the first; the intensities of the stars were such as Arcturus, Vega, etc., would become at thirty-six times their distance.

By coming gradually to the telescope of nine feet focal length, the observer perceived stars of intensity similar to what the stars of the first magnitude would appear at 344 times the distance which now separates them from us.

The eighteen-foot telescope extended its power to 900 times the distance of the stars of the first magnitude; and it was evident that a more powerful telescope would have showed stars still more distant. To escape the numerical consequences that I am going to deduce from Herschel's results, it must be supposed that, among the immense number of stars that each telescope of smaller power discovers, there does not exist one as brilliant as Arcturus or Vega of Lyra; in a word, it must be admitted that stars of the first magnitude only lie near our solar system. Such a supposition does not certainly deserve refutation.

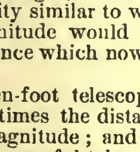


Fig. 22.—The same seen with the naked eye.

There is no star of the first magnitude whose light reaches us in less than three years.

According to that, adds Arago, in conclusion, the light of the stars of different orders, in reality as large as Arcturus, Vega in Lyra, etc., arrives from such distances from the Earth that light could not pass through them—

For stars of the second magnitude in less than	6 years
" fourth magnitude	12 "
" sixth magnitude	36 "
For the last stars visible with the nine-foot telescope	1042 "
For the last stars visible with the eighteen-foot telescope	2700 "

The luminous rays which reach us from the stars relate to us then, if we may so express it, the ancient history of these bodies. But by what power did man arrive at the knowledge of the distances of the nearest stars? In astronomy there are facts which surprise us by their grandeur, and which exceed the sphere of the habitual conceptions of man of such a way that one is tempted to question them with doubt in spite of the affirmation of astronomers, and even to banish them to the rank of the deceitful pretensions with which science is sometimes surrounded, to impose on the vulgar. Of this number are the principal conquests of stellar astronomy, and particularly the determinations relative to the distance of the stars.

I shall endeavor to give an idea of the method which is employed to determine these distances, and by this explanation to remove the unfavorable idea still entertained by many of these perfectly established facts of modern astronomy.

A few instants' reflection will suffice to show, that if the Earth moves in space, during its annual course round the Sun, there must follow an apparent displacement of the other bodies in the sky. No one has looked from the window of a railway-carriage without seeing that the trees, houses, hills, and other objects which sprinkle the country, appear to move in an opposite direction to the path of the train, and that the nearest objects are those which appear to undergo the greatest displacement, while the most distant move more slowly, as far as the horizon, which remains nearly immovable. It must then follow from the movement of the Earth in space, that the stars, situated in the region of the heavens which the Earth leaves behind at a certain time of the year, will appear nearer together, while the stars which the Earth approaches will appear to get farther apart. This effect will be necessarily less as the distances of the stars become greater. If it were possible to measure the displacement undergone by a star in consequence of the movement of the Earth, we should have the distance of this

star. For let the ellipse in Fig. 23 be the curve followed by the Earth in its annual path round the Sun, and let S be the Sun, T S T′ a diameter of the terrestrial orbit, and T and T′ the position of the Earth at the two extremities of this diameter, that is to say, at six months' interval (as the Earth makes

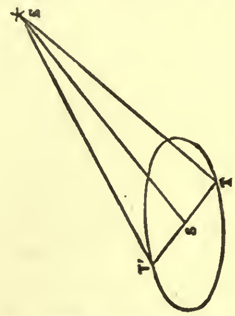


Fig. 23.—Measure of celestial distances.

the entire passage in a year); lastly, let E be the star whose distance is to be measured.

When the Earth is situated at the point T, the angle S T E is measured, formed by the Sun, the Earth, and the star; when the Earth is at T′, the angle S T′ E is measured. It is known that in every triangle the total of the three angles is equal to two right angles, that is, to 180°; therefore, if the total of the two observed angles, S T E and S T′ E, is found, and this total is deducted from 180°, the value of the angle at E will be obtained, the angle subtended at the star by the diameter of the terrestrial orbit. And this value will be as exact as if we could have been transported to the star to measure it directly. The half of this angle, that is, the angle S E T, is what is called "the annual parallax" of the star E. Thus the annual parallax of a star is the angle under which an observer placed on the star would see the radius of the terrestrial orbit

By always taking corresponding observations at two diametrically opposite points of the Earth's orbit in the course of the year, a great number of measures of the annual parallax will be obtained in this manner. In our example, and in our figure, the star is situated near the pole of the ecliptic; the operation is the same, although rather more simple for the other positions of the heavens. In practice, the measures of the angles S T E, S T′ E, are obtained, in an exact way, by comparing the successive positions of the star observed with that of a relatively fixed star which has no parallax. The great majority of stars are among the latter. Astronomical resaerches have proved that there is not a single star with its parallax equal to 1″. They are all below it. To form an idea of this value, it must be understood that, the circumference of astronomical circles used in observation is divided into 360 parts, called degrees, each degree into 60 minutes, each minute into 60 seconds. This value of a second is so small that a spider's thread, placed in the field of view of the telescope, entirely hides the portion of the celestial sphere where the apparent movements of the stars are effected, a portion at most equal to 1″.

The star which these observations have proved to be the nearest, is the star *a* of the Centaur; its parallax is equal to 97 hundredths of a second (0″·97). From the star *a* of the Centaur, the radius of the terrestrial orbit is then reduced to 0″·97. Now, in order that the length of any straight line seen be reduced as to appear only under the small angle of 1 second, it is necessary that this line be at a distance of 206,000 times its length, and in order to reduce it to 0″·97 it must be still farther removed to 211,330 times its length. These are mathematical data. Therefore the distance from us of the star *a* of the Centaur is 211,330 times the radius of the terrestrial orbit, that is to say, 211,330 times 91 millions of miles.

This is the nearest star. Light travels for three years and eight months to come from it to the Earth. The other near stars succeed each other, as we have seen, at greater distances.

From the preceding it will be seen that these results, however prodigious they may appear at first sight, are due to mathematical methods of great simplicity. All the difficulty in this sort of determination consists in the extremely minute, long, and laborious observation of the slight displacement of the star in the heavens.

All these stars, vast as our Sun, separated from each other by such distances, succeeding each other in an endless manner in the immensity of space, are in motion in the heavens. Nothing is stationary in the universe: there is not a single atom of matter in absolute repose. The formidable forces with which matter is animated universally regulate its action. These movements of the suns of space are imperceptible to our eyes, because they are performed at too great a distance; but they are more rapid than any velocity we can observe on the Earth; there are some stars which are carried away in space with a rapidity of fifty miles per second. To the eye which knew how to make abstraction of time as of space, the sky would be a moving swarm of stars.

VI.

VARIABLE STARS—TEMPORARY STARS—STARS SUDDENLY VISIBLE OR INVISIBLE.

Of all the wonders which the telescope has revealed in the fields of space, not one has perhaps more right to the astonishment of mortals than the existence of changing stars, periodically variable, whose light and color undergo a periodicity of brightness; at least, observers have not been more surprised at any telescopic revelation. Stars which, far from remaining fixed in an unchangeable light, see their brightness periodically die away and again revive!—stars shining to-day with a splendid light will be

invisible to-morrow, and after to-morrow again revived! The most daring imagination could scarcely invent such creatures; and now even, when their existence has been well proved, the mind can scarcely accustom itself to realize it.

These are stars whose light undergoes a periodical variation, bringing it by turns to its maximum and its minimum intensity. To figure to ourselves well in what this singular change consists, let us call to mind our Sun, and let us suppose it subjected to these variations. To-day it radiates the most transcendent flames, and pours down into the heated atmosphere floods of dazzling light; for some days it preserves this same intensity; but behold, the sky remaining clear as formerly, the light of the Sun gradually dies away from day to day: at the end of a week it has lost half its light; at the end of fifteen days it can be looked at steadfastly, and then it still fades, becomes pale and dull, only sending a wan light to the Earth.

But it revives, and with it hope. The first progress in its extinguished light is noticed; it becomes whiter and more brilliant. The torch is relighted and increases from day to day; a week after its minimum intensity it already sends forth a light and heat which bring to mind the solar focus. Its increase continues. And when a period equal to that of its decline has passed, the dazzling Sun will have regained all its power and grandeur. The Earth is inundated with the rays of its brilliant light and its fertilizing heat. But it does not enjoy this splendor long, for already the Sun recommences its decreasing curve. And so on, continually. The nature of this new Sun is periodical, while the virtue of our preceding one was to preserve a permanent light and heat.

It may be imagined that these variations of light astonish the observer who contemplates them in the field of the telescope. The periods are of all lengths. For some stars, the thirtieth of the Hydra of Hevelius, for instance, the period is more than 1 year, being 494 days. It varies between the fourth magnitude and complete disappearance. The star χ of the neck of the Swan varies from the fifth to the eleventh magnitude in a period of 404 days. Another star of which we have already spoken in the chapter on the constellations, o of the Whale, also called the Marvellous (Mira Ceti), varies in 334 days from the second magnitude to total disappearance. Other stars are regulated by more rapid variations. The star which passes most rapidly from its maximum to its minimum is Algol in Medusa's Head, which we already know (β of Perseus) For in 1 day 10 hours and 24 minutes it has finished its decrease; in the same lapse of time it has reached its maximum: its period is only 2 days 20 hours 48 minutes. The star δ of Cepheus varies in a period of 5 days 8 hours and 37 minutes, from the third to the fifth magnitude. It will be seen that these variations are themselves very variable, and that there are suns which pass with strange rapidity from their greatest to their smallest light. What are the prodigious forces which regulate these gigantic changes? Science has not yet been able to determine this. Maupertuis said that variable stars were of the form of lenses, that they turned perpendicularly on themselves, and that they presented to us successively their edge and front. At the period when they presented the edge, their light was at the minimum; and at the time when they presented their entire front, it was at their maximum. But do lens-like suns exist? If the thing is possible, it is not proved. Not only are there stars whose light changes periodically, sometimes diminishing until they become completely invisible, although, in reality, they are not quite extinguished; but there are again others whose light is weakened never to be revived, and which forever have disappeared from the sky. These are the extinguished stars of which the list is rather long. The astronomer Ulugh-Beigh stated, in the year 1437, that one star of Auriga, the eleventh of the Wolf, six stars, among which four of the third magnitude near the Southern Fish, all marked in the catalogues of Ptolemy and Abdurrahman-Suphi, were no longer visible in his time. In the seventeenth century, J. D. Cassini, and at the end of the eighteenth, W. Herschel, pointed out a great number of other stars which had completely disappeared. These were systems for which the hour of the end of the world had struck.

Speaking of the end of the world, this dread is awakened in the inhabitants of the Earth, not when stars disappear from the firmament, for this is mostly noticed by astronomers, but rather when a new body is suddenly lighted up in the heavens. Indeed there are stars which suddenly appear. In the same year as the massacre of Saint Bartholomew, on the 11th of November, 1572, a magnificent star of the first magnitude suddenly appeared in the constellation of Cassiopea, effacing by its brilliancy the most beautiful stars in the sky. It remained for eighteen months, and disappeared never to return.

Astrologers said that this appearance was the same as that to the Magi at the birth of Jesus Christ, and concluded from it that the last judgment was near. Thirty-two years later another new star appeared in the constellation of Serpentarius. From the day of its appearance, the 10th of October, 1604, according to Arago, it was white; it surpassed stars of the first magnitude in brightness, also Mars, Jupiter, and Saturn, which were near it. Many compared it to Venus. Those who had seen the star in 1572 found that the new one exceeded it in brightness. It did not appear to become fainter in the second half of the month of October; on the 9th of November, the twilight which effaced Jupiter did not prevent this star from being visible. On the 16th of November Kepler perceived it for the last time, but at Turin, when it reappeared in the east, at the end of

December and at the beginning of January, its light was fainter; it certainly surpassed Antares, but was not equal to Arcturus. On the 20th of March, 1605, it was smaller in appearance than Saturn, but it exceeded in brightness the stars of the third magnitude in Ophiuchus. On the 21st of April it seemed equal to the shining star of the third magnitude in the knee of Ophiuchus. It diminished imperceptibly; on the 8th of October it was still seen, but with difficulty on account of the twilight. In March, 1606, it had become completely invisible.

These appearances, like all extraordinary phenomena, excited terror and awakened ideas, not to be stifled, of the conflagration of the world, the fall of the stars, and the end of time. One of the most memorable predictions is that in 1588, announced in emphatic Latin verse, of which the following is a translation.

"After one thousand five hundred years, dating from the conception of the Virgin, this eighty-eighth year will be strange and full of dread; it will bring with it sad destinies. If, in this terrible year, the perverse world does not fall into dust, if the earth and seas are not annihilated, all the empires of the world will be overthrown, and affliction will oppress the human race."

This prediction was later renewed in favor or disfavor of the seventeenth century, and the *Mercure de France* announced the greatest revolutions for the year 1788. It then passed for having been found in the tomb of Regiomontanus. Authors did not think how right they were to describe this memorable epoch under the title of revolution.

But while considering these predictions, the list of which would be longer than at first imagined, I cannot help relating the curious mystifications worked in 1524 by the German astrologer Stoffler. According to him, on the 20th of February of that year, the conjunction of the planets in the Fishes must produce a universal deluge. Astrologers gave faith to it like the common herd: the sinister news soon traversed the world, and they prepared themselves to see the universe pass from time into eternity. "All the provinces of Gaul," says an author of that period, "were in strange fright and doubt of a universal inundation, and such that our fathers had not seen, or was known by historians or others, by means of which men and women were in great fear. And many removed from their low dwelling-places, and found higher spots, made provision of meal and other matters, and had processions and general and public prayers, that it might please God to have pity on his people."

Fear seized on a great many minds. Those who lived near the sea or rivers left their abodes, and sold, at immense losses, doubtless to unbelievers, their properties and goods. At Toulouse, another Noah constructed a ship to serve as an ark to his family and friends, and, probably, also to a few couples of animals. This was not the only case. According to the account of the historian Bodin, "There were many infidels who made arks to save themselves, although God's promise and oath, never again to drown man by a deluge, was preached to them." Many and many a time the prediction was given out, and, sad to say, it always found the same number of believers, although each time the event gave it a positive denial. In 1584 the fear caused by an announcement of this kind was so great that the churches were unable to contain those who sought refuge in them; a great number made their wills without reflecting that it was useless if all the world was to perish; and others gave their goods to the priests, in the hope that their prayers would delay this day of judgment. I believe that as long as the world remains it will fear its dissolution.

These singular stars which are suddenly lighted up in the heavens, to be extinguished soon after—these variable suns which pass through all degrees of light, and seem, like Castor and Pollux, to have received as a destiny an everlasting transitory movement from life to death and death to life, little suspect the terrors which they so innocently cause to spring up among men. What unknown power presides over these variations of light and heat? What influence on the planetary worlds which circulate round these bodies of so strange a nature? What thought regulates these movements, and what hand constructs beings born to live in harmony with such systems? What distance separates terrestrial nature, where years follow each other by a permanent law, and bring back successively the same phenomena, from those worlds where such prodigious variations take place? The mind is astonished with these questions and cannot answer them.

VII.

DISTANT UNIVERSES—DOUBLE, MULTIPLE, AND COLORED SUNS.

The wonders we have just reviewed become insignificant before those which we approach. Here, what we call natural is quite overthrown. Our observation, ideas formed by experience, classification, and judgment in that which concerns the works of nature, have no longer the least application. We are really in another world, strange, improbable, and unnatural to us. Life, the forces which sustain it, light, heat, electricity, the periods of days and nights, seasons, years, the visible and invisible world, all are transformed. Here we are on the surface of celestial globes, illuminated by many suns, of all magnitudes, lights, colors, and by moons with many-colored disks. Nothing like it has been seen on the earth: are these truly our worlds? are these not other universes?

Let us, then, sum up the studies we have made on the nature of these worlds in our panorama, and let us observe the essential types of the astonishing diversity which contrasts them from ours.

The white light of our Sun pours its dazzling rays from the azure height, and, thanks to the transparent atmosphere in which

a thousand reflections form a real reservoir of light, all the objects which clothe or people the surface of the globe are enveloped in this light. Nevertheless, this white light is not simple. It contains in its rays all possible colors; and bodies, instead of appearing to us clothed with a uniform whiteness, absorb certain colors of this complex ray and reflect others; it is this reflection which constitutes the coloration of these bodies. This depends, then, on the molecular agency of the reflecting surface, on its power of receiving certain rays of the spectrum, and of repelling others. But all these colors constitute the original white—the one source of these various appearances.

It is now well to remember that this theory, applicable to the organic world, receives still more considerable importance when we consider the mode of coloration of organic substances. The beauty of plants, the diversity of the meadows, the gold of the fields, the whiteness of the lily, the scarlet, orange, azure, and the charming shades which form the richness of the flowers, the brilliancy of plumage of little tropical birds, the snowlike doves, the yellow fur of the desert lion, like the radiancy of flaxen hair: it is to the white light of our Sun that we must go for the explanation of these visible beauties—in him resides the source of the infinite shades which decorate the forms of nature.

Now let us, for an instant, suppose that, instead of a white sun, the source of all the light which inundates us, we had a dark blue sun. What a change is soon worked in nature! The clouds lose their silvery whiteness and gold from their flakes, and spreading a darker vault under the heavens, all nature is covered with a colored penumbra, while the beautiful stars remain in the noonday sky; the flowers lose the light of their brilliant dress; the fields succeed each other in the mist as far as the invisible horizon; a new day shines under the heavens.

The carnation of fresh cheeks loses its budding bloom, faces appear to be aged, and astonished humanity asks for the explanation of such a strange phenomenon. We know the rudiments of things so little, and we hold so much to appearances, that the whole universe seems to us renewed by this slight modification of solar light.

How would it be if, instead of an indigo sun, following its apparent course with regularity, making the years and days certain by its own rule, a second sun suddenly arrived in addition to it, a scarlet sun continually disputing the empire of the world of colors with its partner? Imagine at noon, at the moment when our blue sun spreads that shadowy light over nature which we have just described, the conflagration of a resplendent orb kindling its flames in the east. Greenish silhouettes suddenly rise through the diffused light, and opposite each object a dark shadow cuts the blue light which spreads over the world. Later the red sun rises as the other sinks, and the objects are colored, to the east with the red rays, to the west with the blue. Later still, as a fresh mid-day lights up the earth, the first sun vanishes, and from that time nature is clothed with a scarlet fire. If we pass to the night, scarcely have the last rays of the purple sun faded away in the west, like distant Bengal fires, than a new sunrise appears opposite the azured glimmer of the cyclops with the blue eye.

Is it possible for the imagination of poets or the caprice of painters to create on the palette of fancy a more daring world of light than this one? The foolish hand of chimera, throwing on its impressible sheet the odd colors of its will, can it erect at hazard a more wonderful edifice this this? Hegel said that "all which is real is rational," and "all which is rational is real." Yet this bold thought does not express the whole truth. There are many things which do not appear to us rational, and which, nevertheless, exist in reality in the numberless creations of space which surround us.

What we have just said respecting an earth lighted up by two suns of different colors, one being dark blue and the other scarlet, is not imaginary. In a beautiful calm, clear night, take your glass and look at Perseus, this hero walking in the midst of the Milky Way, holding Medusa's head in his hand; look at the star η, this is a world such as that of which we have just spoken. The large star is of a beautiful red, the other of a dark blue. At what distance is this strange system situated? No one can tell. It can only be stated that, at the rate of 186,000 miles per second, light takes more than a hundred years to reach us from thence.

But this is not the only system of the kind. That of γ of Ophiuchus resembles it so much that they may be easily mistaken one for the other (at such a distance it would indeed be excusable) only in the system of Ophiuchus the blue sun is not so dark as in the others. One star of the Dragon very much resembles the preceding, but then the large sun is of a deeper red, its small one bluish; another again, η Argo, has its large sun blue and its less brilliant one dark red.

Thus we have our imaginary world realized in many parts of space. And perhaps there are human eyes who thus contemplate those wonders each day. Who knows?—and the thing is very probable—perhaps they pay no attention to it, and from their cradle accustomed like us to the same sight, they do not appreciate the picturesque value of their abode. Thus are men constituted. The novel and unexpected alone affect them; as to the natural, this seems but an eternal, necessary, and fortuitous state of blind nature, which does not deserve the trouble of being observed. If the people came thence to us, though acknowledging the simplicity of our little universe, they would not fail to observe it with surprise, and be astonished at our indifference.

The suns which constitute these multiple systems differ therefore from ours by their coloration; and, among the whole of the

bodies, a fresh variety again manifests itself. Colored binary systems are not composed solely of the red and blue suns to which we have just alluded; the means have not been at fault; it is the same here as in the universality of the productions of nature; it is from an inexhaustible source that it has drawn the richness and sumptuousness with which it has decorated its works.

For instance, the following is the beautiful system of γ of Andromeda. The large central sun is orange, the small one which gravitates near it is emerald green. What follows from the union of these two colors, the orange and the emerald? Is not this an assortment full of youth, if this metaphor be permitted? A large and magnificent orange sun in the midst of the heavens; then a bright emerald which gracefully joins its green radiations to the gold!

Then, again, in Hercules, we have two suns, red and green; in Berenice's Hair, one pale red, the other a clear green; in Cassiopea, a red and a green sun; a fresh series of soft and charming shades.

Let us change the prospect: to do this, it is only necessary to consider other systems. There is more variety among them than in all the changes which an optician can produce on the screen of a magic-lantern. Certain planetary universes lighted up by two suns have all the series of colors included under blue, and the brilliant shades of gold and purple which throw so much vivacity on this world are there unknown It is in this category that are placed certain systems situated in the constellations of Andromeda, the Serpent, Ophiuchus, Berenice's Hair, etc. Others, again, only know red suns, like a double star of the Lion, for instance. Some other systems are devoted to the blue and yellow, or at least are lighted up by a blue sun and a yellow sun, which only give them a limited series of shades comprised in the combinations of these primitive colors; such are the systems of the Whale, of Eridanus, one of which is straw color and the other blue, the Giraffe, Orion, Unicorn, the Twins, Boötes, the large yellow and the greenish-blue of the Swan; the small one is of an intense blue. We have, on the other hand, assortments of red and green, as is seen in Cassiopea, Berenice's Hair, and Hercules.

Other stellar systems are nearer ours, in the sense that one of the suns which illuminates them has, like ours, a white light, the source of all colors, while its neighbor throws a simple radiation on everything. For instance, in the worlds which revolve round the great sun α of the Ram, the large sun is white; but we constantly see in the heavens another smaller sun, whose blue reflection covers the objects exposed to its rays, as with a veil. The 26th of the Whale is in the same condition, and it is the same with a great number among the brightest stars. Such is the star χ in the Swan's neck, which is besides one of the most remarkable of the variable stars, for in a period of 404 days the large white sun diminishes from the fifth to the eleventh magnitude and returns to its primitive state. To the worlds which gravitate round the principal sun in these binary systems, the original white light appears to give rise to the infinite varieties which we observe on the Earth, with the addition of a blue light constantly coming from the other sun; but to the planets which gravitate round this one, it is the blue coloration which predominates, while the action of the more distant white sun is only secondary.

In the same way as there are white suns, accompanied with blue suns, some are also accompanied with red or yellow suns. But I must not dwell on this enumeration if I wish to review the whole host of the sky.

What a variety of light with two suns, one red and the other green, or one yellow and the other blue, must be experienced on a planet which revolves round one or the other; and what charming contrasts, and what magnificent alternations must arise from a red day and a green day, succeeded in turn with a white day and with darkness! What nature is there! What unimaginable beauty clothes with unknown splendor these distant lands scattered in endless space?

If like our moon which gravitates round the globe, or like those of Jupiter and Saturn, which unite their mirrors on the dark hemisphere of these worlds, the invisible planets which are there poised are surrounded with satellites which constantly accompany them, what is the aspect of these moons, lighted by many suns? That moon which rises from the luminous mountains is divided into differently-colored quarters, one red, another blue; this other only presents an increasing yellow; that one is at its full: it is green, and appears suspended in the heavens like an immense fruit. A ruby moon, an emerald moon, an opal moon—what heavenly jewelry! O night of the Earth, which modestly silvers our solitary moon, thou art very beautiful when the calm and pensive mind contemplates thee! But what art thou beside nights illuminated by these wonderful moons?

And what are eclipses of the sun on these worlds? Multiply suns and multiply moons, to what endless changes must your mutually-eclipsed lights give rise? The blue sun and the yellow sun stand near each other; their combined light produces green on the surfaces illuminated by both of them, yellow or blue on those which receive only one light. Soon the yellow approaches the blue; already it enters on its disk, and the green spread over the world fades, and fades, until the moment when it expires, melted into the gold which pours in space its beautifying rays. A total eclipse colors the world with yellow. An annular eclipse presents a blue ring round a gold-piece. By degrees, imperceptibly, the green revives and holds its empire.

Let us add to this phenomenon another which would be produced if a moon came over the beautiful middle of this gold eclipse, to cover the yellow sun itself and to plunge the world in obscurity, then follow the relations existing between its movement

and that of the Sun, continuing to hide it after its departure from the blue disk, and then to leave nature again fallen under the veil of a new azure. Let us again add—but no, this is Nature's inexhaustible treasure; however much we take from it, it will not be impoverished.

BOOK THIRD.

I.

THE PLANETARY SYSTEM.

We will now descend from the stars as a whole to a particular one; from the general contemplation of our universe to the study of a limited region. After having embraced the extent of this vast and imposing domain explored by science, we shall concentrate our attention on a single point, like the observer who, wishing to give an account of the position of a house in a landscape, after having first examined the neighborhood and places which surround it, concentrates his attention on the house itself. If the immensity of the numbers or the infinity of this expanse no longer present themselves in this new contemplation in a way to astonish our mind and confuse our faculties, the inalienable characteristics which universally distinguish the works of nature will reveal to us more sensible and touching beauties, not less worthy of our attention. In nature's perfect work, the most modest of its creations present the divine sign of their origin, and the most simple unfold a hidden splendor, not less wonderful than the most brilliant manifestations. Thus the splendid coruscations of the Aurora Borealis, which the gigantic shadow of an invisible hand lifts up on the icy pole, are produced in a brighter color, and in a still more charming aspect, on the perfumed corolla of each little flower.

Nevertheless, it must not be imagined that we are going to descend to small objects. They have still colossal forms, at the sight of which the imagination is confused. We are going to occupy ourselves with the system of worlds to which the Earth belongs, and which is commanded by the Sun. Perhaps even we shall feel greater interest in studying things which relate to us more closely, than in those whose distance makes us strangers to their most precious riches.

Here were are at length, arrived nearly at our own abode in space. Descended from the heights of sidereal creation, after having commenced our study with the imaginary circumference which the limits of our sight extended by instruments describe round the point we inhabit, we have gradually approached the centre. Is not the observation of our celestial position more interesting than that of the other cities of space?

The Sun which lights us is one of the stars of the Milky Way, a unit lost in the millions which constitute this nebula. But it is no longer as a star that we must now examine it, but as the centre of a system of worlds grouped around it. Around this luminous body are collected opaque bodies, dark in themselves, and which receive their light and heat from it. These dark bodies are called Planets. To render the study of them more easy, and to help to distinguish them better, they may first be divided into two very distinct groups. The first, near the Sun, is formed of four planets, of small dimensions relatively to those of the second group. These four planets are, in the order of their distances from the Sun, Mercury, Venus, the Earth, and Mars.

The second group, more distant from the Sun, is also formed of four planets; but they are large as compared with the preceding. These four worlds are in the order of their distances from the radiant body, Jupiter, Saturn, Uranus, and Neptune. These bodies are so bulky that the first four united into one would not form one globe of the size of the smallest among them.

Now, between these two distinct groups there is a third, formed of a considerable number of small bodies, of which 109 are already known. These little planets occupy the space which extends from the first to the second group. Compared with the other globes of the system, they are very small bodies indeed, for most of them measure less than a hundred leagues in diameter; and in some even the diameter is only a few miles.

These planets, great and small, are the principal members of the family. We must now add to them some secondary members, satellites which belong to some of them, and are grouped round the planets, like these are round the Sun. Of these satellites, the Earth possesses one, the Moon; Jupiter four, Saturn eight, Uranus four and Neptune probably two.

At what distances are these planetary bodies situated round the central body? Mercury, the nearest, is 35,000,000 miles from the Sun; Venus, which comes next, at 66,-000,000; the Earth, 91,000,000; and Mars, 139,000,000. The group of the small planets occupies a more distant zone, in the mean 266,000,000 miles from the central orb. Then come the four large planets: Jupiter nearly 476,000,000 miles; Saturn, 872,000,000; Uranus, 1,754,000,000; and Neptune, the last, 2,746,000,000 miles. All revolve round the Sun at the respective distances which have been stated, and revolve in more or less time, according as they are more or less distant from that body. The nearest having a shorter path to travel, and being more strongly attracted, revolve more rapidly; the more distant travel slowly, compared to the preceding. The Earth takes 365 days to accomplish its revolution; Mercury only 88, while Neptune takes more than 164 years. These movements are regulated by an admirable and very simple law discovered by the illustrious Kepler, after thirty years of study. Expressed in astronomical terms, this law is thus announced: "The squares of the time of the revolutions of the planets are as the cubes of their distances from the Sun." In other words, by multiplying the number which represents the distance of a planet from the Sun thrice into itself, we have dou-

ble the time of its revolution multiplied by itself. A little attention shows how simple this formidable law, which directs all the celestial movements in space, is. Thus, for instance, Jupiter is five times farther from the Sun than the Earth. I multiply this number three times by itself, $5 \times 5 \times 5 = 125$. Well, this number 125 is precisely double the time of the revolution of Jupiter, multiplied by itself. It is the same for all planets, satellites, and celestial bodies. I must add, for the use of those who wish to go further into astronomy, that these bearings are not rigorously exact, and that if they were, the system of the world would be soon overthrown.

These movements, the formula of which was discovered by Kepler, are caused by attraction or universal gravitation, this law having been discovered by Newton. All bodies in nature attract each other ; the Sun attracts the Earth, the Earth attracts the Moon, and in the infinitely small, as in the infinitely great, the elementary molecules are seen to attract each other by the law of affinity, and to constitute visible matter, which is only an assemblage of atoms in juxtaposition. It is in virtue of this universal force that the worlds launched in space describe a curve round the Sun ; from this rapidly travelled curve would follow a force which, like that with which a stone is animated when it starts from a sling, would throw the planets out of their orbits, if the attraction of the Sun did not hold them captive.

To complete this sketch of the Empire of the Sun, we must add to the preceding, certain bodies which, without departing from his kingdom, are always journeying. From time to time they pay a visit to the capital, then return to the provinces, at every imaginable distance. These are comets, wandering beings, if ever there were any, indefatigable travellers, but which the powerful attraction of the solar body always retains in the limits of his domain.

Such is the little group of worlds of which our Sun is the sovereign.

Imagine a magnificent vessel, the Great Eastern for example, sailing in the open sea. Around it move a quantity of little boats, which are insignificant in comparison, and around some of these boats children's little boats, like those we see in the ponds in our squares. The boats placed at different distances move round the large vessel, and the toy-boats revolve round these boats. Lastly, a quantity of canoes alternately recede from and approach the large vessel, moving in ellipses.

This fleet of various small vessels is not immovable on the ocean : and this is the most wonderful point. Besides all the circular movements of which I have just spoken, we must see the collective movement of the fleet, carried away on the liquid plain by the master vessel. Fixed in the middle of the boats which revolve round it, the brilliant great ship sails on the ocean, drawing with it all its little satellites without their perceiving it, occupied as they are in faithfully revolving round the centre. So the Sun which it represents sails in space, drawing with it the Earth, Moon, planets, comets, and all its system. Where is it going ? Toward what point are we all directed ? Which is the point in space which sees our great fleet advancing toward it ?

It would be difficult for me to tell you if we are going to strike against a rock or to cast anchor in a gulf ; I rather believe that we shall continue our path indefinitely, describing a gigantic orbit in the heavens. We are actually approaching an imposing constellation, the constellation of Hercules, situated between Lyra and Boötes. One day a small star will be seen to arrive in this constellation, between the stars μ and π at a quarter of the distance from the second to the first. At this period the general aspect of the constellation will begin to change to us, seeing that the stars which we approach will get farther from each other, as those which we leave behind will draw nearer together, and those on each side of us seem to fall back ; but this period is so distant from us that the best eyes cannot reach it. It is true the Sun carries us away with a velocity of about two leagues per second, but there is such a distance between each star that this progress is almost insignificant. It must be remembered that there are stars whose movement is still more rapid.

Such is the aspect under which it is proper to comprehend the Sun in passing from its *rôle* of star to that of the head of a system. Now this last *rôle* will be the only one that we shall study. The stars being suns, it is more than probable that to study and completely understand their history they must also be considered under the same aspect, and be equally surrounded by their respective families ; but these families are unknown to us, and man's mind is so constituted that it is difficult for him to entirely comprehend the sphere of known things, and he would be easily lost did he try to go beyond. Moreover, we always preserve, whatever we do, a little background of egotism, and we gladly reserve our attention for persons or things which touch us nearest. We have now passed definitely from sidereal to planetary astronomy.

II.

THE SUN.

THE resplendent body which shines over our heads occupies the centre of the group of worlds to which the Earth belongs. Our planetary system owes its existence and life to it. It is truly the heart of this gigantic organism, as expressed in olden times by a happy metaphor of Theon of Smyrna, and its reviving pulsations sustain its long existence. Placed in the midst of a family as father, over which it ceaselessly has watched from unknown ages when the worlds left their cradles, it governs and directs, both in the maintenance of its interior economy and

in the individual *rôle* which it fills amid the universality of the sidereal creation. Under the impulses of the forces which emanate from it, or of which it is the pivot, the Earth and our companions the planets gravitate round it, imbibing in their eternal courses the elements of light, heat, and magnetism, which constantly renew the activity of their life. This magnificent body is, at the same time, their support in space, the fire which warms them, the lamp which lights them, and the fertile source which pours out on them the treasures of existence. It is he who permits the Earth to float in the heavens, held by the invisible network of the planetary attractions; it is he who guides it in its way and distributes to it years, seasons, and days. It is he who prepares a new clothing for the sphere yet frozen in the nakedness of winter, and who invests it with a luxuriant dress when it inclines its pole covered with snows toward him; it is he who gilds the harvests in the plains and ripens the heavy grape on the warm hills. It is this glorious body which, in the morning, spreads the splendor of the day over the transparent atmosphere, or rises from the sleeping ocean, which he will transform into charitable dew for the thirsty plains; it is he who forms the winds in the air, the twilight breeze on the shore, the ocean currents which traverse the waters. It is again, he who sustains the vital principles of the air we breathe, the circulation of life in the organic kingdoms, in a word, the regular stability of the world. Lastly, it is to him who we owe our intellectual life and the collective life of entire humanity, the perpetual food of our industry; and more than this, the activity of the brain which allows us to clothe our thoughts with a form, and mutually transmit them in the brilliant intercourse of intelligence.

What imagination is powerful enough to comprehend the extent of the Sun's action on all the bodies subjected to its influences? A million and a half times larger than the Earth, and seven hundred times larger than all the planets together, he represents the whole planetary system; and this system, which is a mere nothing compared with the stars, he draws through the deserts of space; and these worlds follow him at his will like dark passengers carried away by a splendid vessel on an endless sea. He makes them revolve round him, that they themselves may imbibe in their course the support of their existence; he governs them with his royal power, and regulates their formidable movements.

From these striking manifestations of his power, let us now descend to his hidden actions. Let us see his light and heat act on the organism of the planets which regard him with love and take long draughts of his fertile rays, on the electricity of minerals and on the diurnal variations of the magnetic needle, on the formation of clouds and the coloration of meteors; let us see them, these occult influences of light and heat, descending through the pure air even to our very souls, so eminently accessible to exterior impressions, and communicating to them joy or sadness, and perhaps we shall begin to form an idea of what a ray of sunlight is, in the infinitely small of terrestrial nature as in the infinitely great of sidereal phenomena.

But what is the nature of this powerful body whose action is so universal, which he burns in this vast censer, what are the fragments which constitute this splendid globe? Does it contain in itself the conditions of an infinite duration or is the Earth rather destined one day to see this lamp of life extinguished, and revolving henceforth in the darkness of an eternal winter? These questions belong to a lawful curiosity, and we wish that a satisfactory answer could be made to them. When we wish to appreciate the nature and greatness of a high person, we do not generally seek to prove his defects, to study the blemishes in his character; this would be a singular way of judging his value; and even were this so, we owe it to human imperfection, from which the greatest of us are not free. But if referred to a being whose distinctive character lay precisely in being not only of a magnificent purity, but also the source of all light and purity, people would not seek for spots to understand him. Indeed, the learned were very astonished 260 years ago, when King Sun, the god of day, was accused by the telescope of being constantly covered with spots; and would it not be still more astonished if it discovered that these spots were precisely the only means that the Sun gives us to penetrate his nature? They almost believed on this occasion that pride is in the inverse ratio of worth. The official *savants* of that time, the theologians and disciples of the school of Aristotle, were not willing to believe anything. The provincial father of the order of the Jesuits at Ingolstadt, replied to Scheiner, one of the first after Galileo who had seen the Sun and its spots through a glass, that Aristotle had proved that, in general, all stars were incorruptible, and that the Sun in particular was the purest light possible, consequently that the pretended spots of the Sun were in the glasses of his telescopes or in his eyes. When Galileo made the same observation, the Peripatetics exerted themselves to prove to him, books in hand, that the purity of the Sun was invincible, and that he had seen badly. And, indeed, who would have suspected such a thing! Spots on the Sun! This must be an error, and an evident delusion!

However, the Sun has spots, and the most curious fact is that these spots have enabled us to know its nature and physical constitution, while without them we should not have been able to acquire the slightest notion of the disposition of this great body.

Let us see, then, in what the spots of the Sun consist.

Generally, this is the aspect which they present to us in the field of the telescope. (See Fig. 24.) Two very distant portions are noticed. At the centre a well-defined black region. Around it a region not so black or

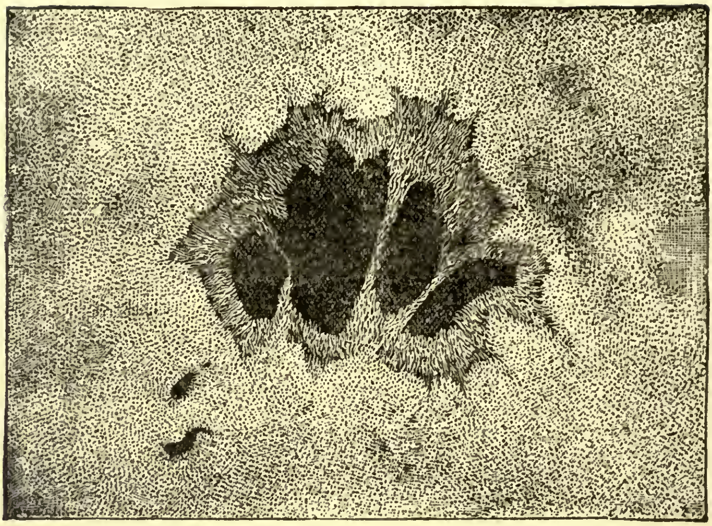


Fig. 24.—A Sun Spot.

grayish compared with the surface of the Sun which surrounds it. The central part has received the name of umbra ; sometimes at the centre of this part is noticed a more intense dark spot, which is called "the nucleus." The exterior region of the spot has received the name of "penumbra." When it is stated that the centre of the spot is black, this expression must be understood as relative to the general surface of the Sun ; for this centre, however dark it may appear by contrast, has been found of a light equal to two thousand times that of the full Moon.

We may be led to the belief that these spots, generally invisible to the naked eye, are insignificant movements carried on on the Sun's surface, and of small extent. It is not so. They are daily and very important phenomena. Some of them have been known to measure 80,000 miles ; that is to say, they are ten times larger than the Earth. Our globe falling into most of them would be lost as in a well. Besides being of this size, they are also the seat of various actions and prodigious phenomena. They are not formed suddenly as a whole, but increase to the limit they attain, and afterward diminish. Some only last a few weeks, others months. Now the movements with which they are animated, either for their increase or diminution, or in their internal action, are sometimes of unheard-of rapidity. Lately astronomers have followed a dazzling meteor passing through a group of spots with a velocity of two thousand French leagues per minute. In other parts they have watched circular whirlwinds, dragging into their commotion large spots like the Earth, and swallowing them up in abysses with fearful velocity. Sometimes are seen the crests of stormy waves extending over parts of the penumbra, and rising on the white surface of the Sun as a still whiter and brighter substance, doubtless projected in their ebullition by interior forces. There have, besides, been seen immense bridges of fiery substances cast suddenly over a black spot, crossing it from one end to the other, like an arch of luminous striæ, which sometimes is dissipated, and falls down into the abysses of lower whirlpools. This body, which each day pours out over our heads such a pure and calm light, is the seat of powerful actions and prodigious movements, of which our tempests, hurricanes, and waterspouts give us but a slight idea ; for these gigantic disturbances are not performed, as here, in an atmosphere of a few leagues thickness and over a few leagues area, but in proportions as vast as its atmosphere, which rises thousands of leagues above its surface,* and as its volume, which exceeds 1,450,000 times that of our globe. One of the first results of the observation of solar spots was to discover that the Sun turns on its axis in about twenty-five of our days.

Indeed, if we watch for several consecutive days any of the spots visible on the solar surface, or a group of spots, or even the whole Sun, we shall not be long in remarking that the spots are all animated with the same movement from one edge to the other of the solar disk. If, for instance, we begin to follow a spot from its appearance at the eastern edge, we observe that it advances slowly toward the middle of the body, which it reaches about seven days after its appearance ; then it passes it, and continues its course toward the west, and seven days

* The recent spectrum observations tend to disprove this.—Tr.

after it reaches the edge and disappears.

After a period of fourteen days, employed in travelling over the opposite hemisphere, it reappears at the same place, and follows the path previously pointed out. These observations evidently show that the Sun turns on an axis. This rotation of the Sun shows its spots in the following manner:

If the period of the reappearance of the spots is from twenty-seven to twenty-eight days, this does not refute the number of twenty-five days before mentioned. The difference proceeds from the Earth not remaining immovable in space, but turning round the Sun. In order that we might observe directly the duration of rotation, it would be evidently necessary, as a first condition, that we should remain at the same place; for otherwise, if we turn round the body in the direction of its movement, we should still see the spots after the moment when they are invisible at the point where we were at first; and if we go in the contrary direction, we shall cease to see them before they cease to be visible at the same point. Now, in its translatory movement round the Sun, the Earth, advancing in the direction of its rotation, sees the spots two

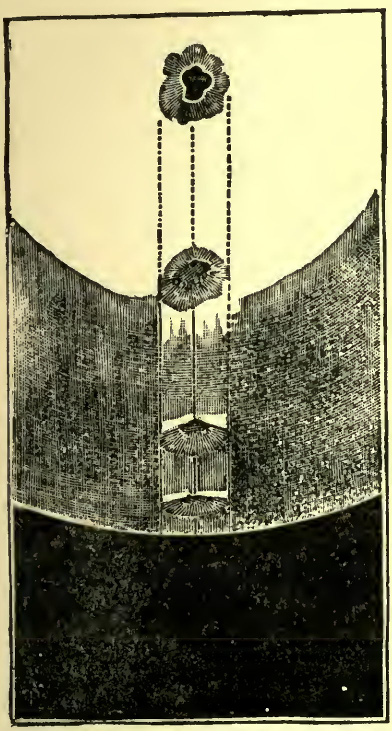


Fig. 25.—The Sun's Rotation.

days and a half after they have disappeared at the point where the Earth was at the commencement of the observation.

This rotatory movement takes place from west to east, like that of the Earth and all planets of the system. Thus by telescopic examination, this body declared fixed and incorruptible in antiquity, is stripped of its two distinctive qualities. The diurnal rotation of the Sun is twenty-five times longer than that of the Earth; but it differs essentially in its immediate consequences, because it does not produce on the surface the alternate day and night which we derive from this movement. It cannot, then, be stated that this is the length of the solar day, for it is not the sign of a succession of light and darkness: the Sun's day does not go out, and the twilight of evening does not pale it. This world lives in a permanent light.

It neither knows our seasons nor years, and the elements of our calendar cannot be applied to its astronomical *rôle*. It seems that the rapid succession of things which constitute our time, and the changing series of phenomena which we experience, do not fall to his lot; continuance and endless duration are his appanage; and he is freed from counting for his individual personal life these successive ages which measure life and overwhelm it with their number. The great variety of nature separates it from the rank of the planetary world; and it would be a profound subject of astonishment to an inhabitant of the Earth if he were to visit a country so essentially distinct from ours, and to be able to establish a comparison between this strange world and his own.

III.

THE SUN (CONTINUED).

WHATEVER may have been the preconceived idea by which opinions were regulated in favor of this beautiful Sun, this radiant body, so venerated that the idea of accusing it of spots was a blasphemy, it is nevertheless from observation and study of these spots that the knowledge we have of it has been acquired; so true is it that Science, superior to all prejudices, is the real ruler of the mind. The examination of these spots—their form, and the changing aspects which they reveal in consequence of the rotation of the Sun (Fig. 25), has served as a basis to a theory of its physical constitution which many astronomers have successively adopted and established, from Wilson and Herschel to Humboldt and Arago. According to this theory, the Sun is essentially composed of a nucleus and an atmosphere. The nucleus is dark, and the atmosphere is enveloped with a luminous stratum, to which has been given the name of "photosphere." The light and heat which it sends out to us does not come from the nucleus, but from this calorific and bright envelope. The spots are explained by supposing that they are openings formed in this outer envelope, either by gaseous eruptions issuing

from volcanoes, or by powerful currents rising from the lower to the upper atmosphere, similar to vertical hurricanes, or by quite another cause dependent on the nature of the body. The penumbræ of the spots are formed on this theory by the lower atmosphere being endowed with the property of reflecting the light and heat of the photosphere and keeping it from the body of the Sun. The dark centre of the spots is nothing else but the body of the Sun itself, rendered visible by the aperture of the lower atmosphere corresponding to the opening of the photosphere. The spots are in this manner sufficiently explained, and also the different appearances observed on the solar surface, such as the pores with which it appears separated, faculæ or white spots, or ridges, phenomena caused by chemical movements carried on in the atmosphere in which various gases are mixed in the most varied combinations.

This theory has appeared much better established since the funnel-like aperture which forms the spots becomes still more perceptible by the perspective views afforded by the rotatory movement of the Sun. In virtue of this movement a round spot appears, and narrows in proportion as it travels farther from the centre; and when the portion of the sphere where it is situated disappears while it keeps its entire length, its width diminishes until it presents only the appearance of a line. Moreover, the portion of the penumbra, or, in other words, of the funnel which is on the side of the spectator, will diminish in width, and will disappear before the rest. Lastly, when a large spot arrives at the edge of the disk, if this spot is large enough, it ought to be seen slightly hollowing the part of the solar disk which it occupies. Now these appearances, regulated by perspective in the case of the spots being openings, are precisely those which are observed.

Astronomers are then generally of opinion that the solar nucleus is an opaque body, dark, like the Earth; that it is surrounded with a fluid atmosphere; and beyond this fluid lies a layer of substance endowed with the property of emitting light and heat; it is this outer stratum which is called the photosphere.

I say astronomers are generally of that opinion, for they are not all unanimous. A few years ago the physical sciences were enriched by a wonderful discovery, of which I shall speak farther on, by which light may be analyzed—that is to say, the elements whence it comes may be known. Now, the English and Germans, to whom we owe this discovery, having examined the nature of the solar light, found that there were in the Sun's atmosphere iron, sodium, potassium, barium, etc., while there was no gold, silver, copper, or zinc. This would have been in opposition to the alchemists of past times, Nicolas Flamel in particular: the Sun was to them a golden body *par excellence*. All these materials, proved to exist in the body by spectrum analysis, were also revealed as being in a state of incandescence. So much, then, for the experimenters and theorists of whom I speak—the orb of day returned to what it was to our fathers—a body of fire. Indeed, not only did they again state that the torch of day, far from being dark, is an incandescent globe: that the light we receive from it comes from its fiery nucleus, and not from its atmosphere; but they again sought to explain the spots on this new hypothesis, and they proposed to admit that these spots were simply clouds, combining with each other in the solar atmosphere under the influence of a partial fall of temperature, and becoming opaque enough to intercept the light of the incandescent globe almost entirely. Other *savants*, sharing the same ideas on the physical constitution of the Sun, threw out the idea that spots were not clouds, but partial solidifications of the surface—scoriæ, such as we see form on the surface of boiling metals treated in a crucible. They explained even how the umbra of the spots is the thickest central part of these partial solidifications, which intercepts the rays emitted by the solar body more effectually as it is more solid, and that the penumbra would correspond to the pellicle which, in every formation of this kind, is observed on the surface of melting metals, to be produced invariably round the scoriæ. But although, having cleared science on some important points, and having rendered it good service, these researches are far from being ended, and founded on a solid theory; they have not yet upset the reigning theory before explained.

The size of the Sun, 1,400,000 times larger than the Earth, exceeds the degree of our habitual measurements too much for us to hope to give a sufficient idea of it. In the matter of volumes, as in that of distances and times, the numbers too much surpass our ordinary conceptions to appeal to our minds, and every care that we take to represent them to ourselves remains almost sterile. Nevertheless, a comparison will be able to inspire at least a nearer idea of the size to which we refer. If we placed the terrestrial globe in the centre of the solar globe, like a kernel in the middle of a fruit, the distance of the Moon would be included in the interior of the solar body; the Moon itself would be absorbed in it, and beyond the Moon to the surface of the Sun, following the same radius, we should still have to traverse a distance of 160,000 miles. From the Earth to the Sun are reckoned 91 millions of miles. It is on account of this great distance that this immense body only appears to measure a foot in diameter; and this explains why the ancients, and Epicurus in particular, did not believe it larger than that measure. This distance equally explains why it does not appear to us larger than the Moon, which is only 240,000 miles away. From this it may reasonably be asked, how this distance from the Sun to the Earth could possibly be determined. The method is too complicated

for me to explain it here in detail; but an idea may be given of it without exceeding the limits of this chapter.

Between the Sun and the Earth there are two planets, Mercury and Venus; the latter has rendered the greatest service in the study of the distance which separates us fom the Sun. As its orbit (the circumference which it describes round the central body) is nearly on the same plane as the Earth's orbit, it happens from time to time that it passes between the Sun and ourselves, and appears like a black spot crossing the luminous disk. This passage takes place at the singular intervals of eight years, 113½ years—8 years, 113½ + 8 years. At these valuable periods astronomers of all countries forget their nationality, and listening to each other like brothers, place themselves so as to observe the passage of Venus in different countries. Two observers situated in the stations most distant from each other note the two points where the planet, seen from each of their stations, seems to be projected at the same moment on the solar disk. This measure gives them the angle formed by two lines starting from their stations, and crossing each other on Venus, and passing on to the Sun. It is the measure of this angle, made by observers placed on all parts of the globe, which gives what is named the parallax of the Sun.

At the last transit of Venus, a French astronomer, Le Gentil—his name should have preserved him from such disappointments on the part of Venus—was curiously requited for his love of science and his disinterestedness. Sent to India by the Académie des Sciences, he embarked with arms and baggage to observe the passage of the planet in 1761 at Pondicherry. His great activity and ardor could not conquer the chances of the sea voyage; he landed a few days after the phenomenon had taken place. . . . The obstacles irritated him and increased his courage. He took the heroic resolution of remaining for eight years in the midst of that unknown country, in order to compensate himself for his lost observation; he waited for the passage of 1769, and then took all desired arrangements to make a perfect observation. The year and the day at length arrived! The sky was pure, no obstacle hindered his long resolution from at last receiving its reward. But alas! exactly at the moment when the black spot was about to enter on the solar disk, a small cloud formed in the atmosphere and remained before the Sun until the momet when Venus left the disk, putting an end to the possibility of all observation. The astronomer again took the voyage to France with a stormy sea, which brought his days to a close. Le Gentil, of Galaisière, died in 1792, after having written an account of his travels.

From considerations based on the magnetic action of the Sun, we may be led to believe that its light is of the same nature as the electric light, only incomparably more powerful, seeing that the elements which we have at command are infinitely inferior to those commanded by nature. However bright our electric foci may be, however dazzling their light, the whiteness of which astonishes us when it is projected on the solar disk, the electric light has the appearance of a black spot.

The intensity of solar heat is not less difficult to conceive; the most intense of our furnaces, which rise to the temperature of white heat, does not give us a faint idea of it.

However, the following few comparisons will indicate its value. If we represent the Sun under the form of an enormous globe built up of a million four hundred thousand terrestrial globes, and covered entirely with a stratum of coal fourteen miles thick, the heat which it pours out annually in space is equal to that which would be furnished by this stratum of flaming coal. This solar heat would also be capable of melting in one second a column of ice which would measure 1590 square miles at its base, and 192,000 miles high.

Lastly, it is curious to inquire how much this gigantic body weighs. It is a good weight:

2,154,106,580.000,000,000,000,000,000 tons!

If this globe were in the present day, as in that of Apollo, drawn by four horses, it would be necessary that the coursers had exceptional strength, especially to be able to go round the globe in twenty-four hours. Now, following the Sun's weight, that of our Earth, expressed like the preceding in tons, is 6,069,000,000,000,000,000,000.

When astronomers place the Sun in one of the pans of the immense scales with which they determine the weight of the stars, it is necessary for them to put in the other one 350,000 terrestrial globes to restore equilibrium.

We need not fear that this gigantic body will one day be extinguished, leaving the Earth in icy darkness. It possesses in its colossal reservoir a sufficient number of degrees of heat for us to have before us millions of centuries, during which it would be impossible for us, even if this heat should decrease, to perceive it.

Yes, the resplendent star of day remains to us the most beautiful and the best of stars. We have observed its size and its power: no power is capable of rivalling it, science has not lessened its venerated image in our mind, and, as in our preceding studies, reality here is superior to fiction. Our homage remains, better understood and justified than ever.

IV.

MERCURY.

Above the Sun, in the west, when that radiant body sets, or again before its rising in the east, is seen sometimes a small white star, slightly tinged with red. The Greeks

called it Apollo, god of day, and Mercury, the god of thieves, who take advantage of night to commit their misdeeds; for they saw in it two different planets, one a morning and the other an evening one, as they did also for a long time in the case of Venus, the Egyptians and Indians doing the same. The first gave it the names of Set and Horus; the second those of Boudda and Rauhineya; names which bring to mind, like the preceding, the divinities of day and night. The Latins, who, however, employed themselves very little with astronomy, in this respect remained in doubt. It has been only in later times that the identity of these two stars which, like Castor and Pollux, to which they are assimilated, never appear together,

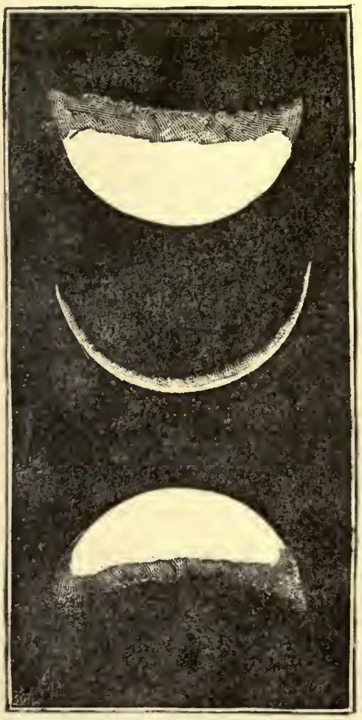


Fig. 26.—Phases of Mercury.

has been proved: its evening name, Mercury, was the one retained.

Being the first planet of the system, Mercury always remains absorbed in the royal radiation of the prince of day; also, like a courtier, it is deprived of its individuality, and lended in the personality of the ruling star. It gains nothing and loses much, seeing that it had not the honor of being known to the founders of astronomy. Copernicus despaired of ever seeing it. "I fear," said this great man, "that I shall descend to the tomb without having seen the planet." And, indeed, he who had transformed the system of the world, and taken in hand each of the planets to place them round the Sun, died without having seen the first among them. Galilèo was able to observe it, thanks to the glasses which he had invented, but it could not be said he understood it sufficiently, as it was impossible for him ever to distinguish its phases. The adversaries of the new system opposed the first astronomers. Copernicus, Galileo, and Kepler, on account of the absence of phases in the planets Mercury and Venus. "For," said they, "if these planets revolved round the Sun, they would change their aspect to our eyes, as the Moon does, according as we see in front, in profile, or in rear, the illumined part, the side in fact which they turn toward the sun."

Copernicus and his colleagues replied: "We do not distinguish any phases, it is true; but if it only requires them in order that you should adopt our system, God will cause that there may be some." Indeed there were some, and here (Fig. 26) are those of Mercury. By the observation of the irregularities visible in the interior of the crescent or quarter, it has been observed that Mercury is rugged with high mountains, higher than those of the Earth, although Mercury is a much smaller globe than ours. The existence of a denser and higher atmosphere than ours has been suspected. In the middle of the last century, one of the numerous romancers who feigned voyages to the planets pretended to know that the mountains of Mercury were all crowned with beautiful gardens, in which grew naturally not only the most succulent fruits, which served as food to the Mercurians, but also the greatest variety of dishes. It would appear that in this happy world it is not necessary to prepare, as with us, things for food; fowls, hams, beefsteaks, cutlets, entremets, small side-dishes, etc., were raised there in the same manner as the apples on our apple-trees, and when a repast was wished for, it was sufficient to spread the cloth; then arrived bird-waiters for your orders, who knowingly flew away, and in the twinkling of an eye, from the mountains, where the desired dishes were to be found, brought you them with the greatest haste. It is better, perhaps, to believe that the vegetables of Mercury possess these precious gifts, and that its birds are of such delightful intelligence, than to think, with Fontenelle, that the inhabitants of Mercury are all mad, and that their brains are burned with the violent heat which the Sun pours upon their heads. But until an authentic voyager has made us sufficiently acquainted on this head, we will confine ourselves to the astronomical elements of the planet. It revolves at a distance of 35 millions of miles from the Sun; its diameter is 2960 miles; its day is 24 hours 3 minutes 28 seconds long; its year, 87 days 23 hours 14 minutes; and its seasons, 22 days only; its mass, compared to that of the Earth, is only $\frac{17}{100}$; its density is three times more than ours, and bodies which fall on its surface travel 7·45 feet during the first second of fall; and, lastly, it receives six times and a half more light and heat than the Earth does. Its orbit is very eccentric.

Eccentric means that in its movement of

revolution round the Sun it does not always remain at the same distance from it: that it describes an ellipse rather than a circle. As a result, at certain epochs of its year it receives twice as much heat as at the opposite epochs. It will be seen that the word excentric is not badly chosen, as it represents a want of regularity in the circular movement of the planet. While we are speaking of this singularity, let us also add that of all bodies Comets are the most eccentric. At certain times they approach so near the Sun that it is thought that they will be melted in his flames; in the opposite part of their path, on the contrary, they go to such distances that they are lost to sight, and wander in the darkness and cold of solitary space.

V.

VENUS.

SOME ill-disposed minds have asserted that although Venus is beautiful afar, it is frightful on a nearer view. I fancy I see my young and amiable readers; and I am sure that not one among them is of this opinion.

Indeed, all the magnificence of light and day which we enjoy on the Earth, Venus possesses in a higher degree. Like our globe, it is surrounded by a transparent atmosphere, in the midst of which are combined thousands and thousands of shades of light. Clouds rise from the stormy ocean, and transport into the sky, snowy, silvery, golden and purple tints. At morning and evening, when the dazzling orb of day, twice as large as it appears from the Earth, lifts its enormous disk at the east, or inclines toward the west, the twilight unfolds its splendors and charms. From here we can be spectators of this distant spectacle; for we distinctly see the daybreak and the close of day in the plains of Venus. Day and night are of nearly the same duration as on the Earth; the diurnal period of rotation of the planet is twenty-three hours twenty-one minutes seven seconds; it is consequently thirty-five minutes less than ours. But between winter and summer there is a still greater difference than with us between the intervals which elapse from the rising to the setting of the Sun and that which separates its setting from its rising; for this globe is more inclined to the plane of its orbit than ours. It is this inclination which constitutes on this planet, as on the Earth, the variation of seasons, their duration and intensity. Venus being still more inclined than the Earth to the plane in which it moves, its seasons are more characteristic than ours, and its climate much more marked. Between the cold of winter and heat of summer there is a much greater difference than here; it is almost as cold in winter and very much warmer in summer. From the equator to the poles there is also a more decided variation of climates than on the terrestrial sphere; our temperate zones are imperceptible on Venus, and do not exist even. The torrid and glacial zones constantly encroach on each other; and as the year only occupies two hundred and twenty-four days instead of three hundred and sixty-five, the rapidity of this succession adds to its intensity. The snows, also, have not time to accumulate at the poles as on the Earth, Mars, and Saturn; and the atmospheric variations cause a continual disturbance on the surface of the planet. Its mountains are much higher than ours. They have been measured at the period when Venus presents itself to us as a crescent. The inequalities which are noticed in the interior of the crescent are the highest points of the surface, which still receive the Sun's rays after these have left the plain. The height can be concluded from the time that these light-points take to disappear. We have just spoken of

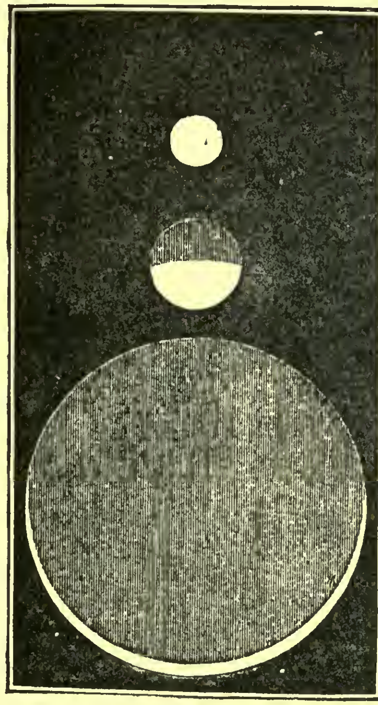


Fig. 27.—Variations of the apparent disk of Venus.

Venus as a crescent. Like Mercury, this planet is situated between the Earth and the Sun; and the circle which it describes during its year is comprised in the circle which the Earth describes round the same body. Hence it follows that at certain epochs the planet Venus is exactly between us and the Sun; and then it presents its dark part to us, as its illuminated portion is naturally on the side of the Sun. At other times, when it is to the right or left of the Sun, it presents only a quarter. Lastly, when Venus is on the other side of the Sun, it presents its entire illuminated portion to us.

As Venus revolves in an orbit, there are periods when it is only about twenty millions of miles from us (when it is between us and the sun), and contrary periods when it is 157

millions of miles distant from us. Its apparent dimensions then vary very perceptibly with its distance. Fig. 27 shows these variations.

The phases of Venus were seen for the first time by Galileo in the month of September, 1610, who beheld this spectacle with a joy impossible to describe, seeing that it eloquently testified in favor of the system of Copernicus, showing that, like the Earth and Moon, the planets receive their light from the Sun. When I say that these phases were for the first time seen in the month of September, 1610, you must not conclude that they did not exist before that epoch, but you must understand that before that year no one had turned the telescope to the planet, and that with the naked eye these phases are imperceptible.

According to the custom of the period, the illustrious astronomer disguised his discovery under an anagram, to maintain the authenticity of this discovery in case of rivalry, and to give himself time to continue his observations and to perfect them. He finished a letter with this phrase: "Hæc immatura a me jam frustra leguntur, d. y." which means, "These things, unripened and as yet hidden to others, are at length read by me."

Under this cryptogram it would be difficult to discover the idea of the phases of Venus. Our fathers were very ingenious, and in the present time certain discoveries would not have been so greatly contested, if astronomers had sometimes used the same ruse. In this phrase there are thirty-four letters. By placing them in another order we get these words, in which the whole discovery is elegantly inscribed: "Cynthiæ figuras emulatur mater Amorum." "The mother of the Loves puts on the phases of the Moon."

Galileo was very cunning. Two months later, Father Castelli, asking if Venus had phases, he replied, "My state of health is very bad, and I find it better to be in my bed than in the dew." It was only two days before the end of the year that he announced the above discovery.

Has Venus a satellite? "It would rather have two than one," replied the friend of Cassini to the enemies of this astronomer. Many hold the firm belief of having seen it, but the question remains undecided. In the middle of the last century it was so strongly believed in that Frederick the Great, of Prussia, proposed to give it the name of his friend Alembert, from which the illustrious geometer excused himself in this little note: "Your Majesty does me too much honor in wishing to baptize this new planet with my name. I am neither great enough to become the satellite of Venus in the heavens, nor well enough to be so on the Earth; and I know too well how small a place I occupy in this lower world to covet one in the sky."

This globe presents the greatest resemblance to our own; and it has nearly the same astronomical elements, size, volume, weight, and density; only it is much nearer to the Sun than we are. From the commencement of ancient poetry, its position near the Sun, which causes it to appear at sunrise and sunset, attracted contemplative minds toward it, and Venus became the star of all those who love to dream in the evening, from the shepherd returning from the fields to bosom friends whose souls commune with each other during the night. In the middle ages a worthy father took an ecstatic voyage in the heavens, and in Venus saw only young people of ravishing beauty, living in the midst of perfect happiness; in his sight these were the guiding spirits of the planet Venus, for in olden times it was believed that a legion of angels or genii presided over the direction of each of the heavenly spheres. Later, the author of "Paul and Virginia" gave the most wonderful description of Venus; it was a real terrestrial paradise.

VI.

MARS.

All the maledictions of mortals have fallen on Saturn and Mars. Beginning with war, that scourge of humanity, of which it will have great trouble to rid itself, all public misfortunes caused by power have been attributed to Mars, who, if it knew what the Earth thought of it, ought to regard us with an evil eye. It is, nevertheless, innocent of all these calumnies, and we ought not to speak ill of it, presenting, as it does, most resemblance to ourselves. Indeed the world of Mars resembles the Earth so much that if we happened one day to be travelling there and lost our way, it would be almost impossible to recognize which of the two were our planet. Without the Moon, which would charitably remove our uncertainty, we should run a great risk of arriving among the inhabitants of Mars, expecting to descend into Europe or some other terrestrial quarter. Indeed the planet Mars in our telescopes presents the same aspect as the Earth must do to the inhabitants of Venus—a circular disk, rather flattened, turning on itself in about twenty-four hours, furrowed from time to time by fleeting clouds, diversified with here dark and there light plains; revolving obliquely on an axis enveloped with an atmosphere and with snow-covered poles. On this planet the seasons are nearly of the same intensity as our own, but their duration is twice as long; for Mars only accomplishes its annual revolution round the Sun in 1 year 321 days and 22 hours, or 1 year 10 months and 21 days. The masses of ice at its poles partly melt in the spring of each hemisphere, and again form in the autumn, as occurs on our globe; and as the seasons are complementary on both hemispheres, the southern pole diminishes while the northern pole increases, and alternately. From this melting of snows result the changes of temperature and the cloud movements which are observed; one part of the water is evaporated into clouds, the other part swells the rivers and descends to the sea. Thus the fundamental characteristics of the terrestrial seasons are again found on the neighboring planet.

We may, nevertheless, notice certain differences between the aspect of Mars and our own world. Whereas the Earth seen at a distance must appear tinted with green, on account of the color of its atmosphere, its vegetation, and waters, Mars is shaded with red, and it is this shade which gives it the reddish light with which it is seen to shine. Doubtless this characteristic color is produced by the dominant coloring of its surface; either its soil is thus colored like that of our deserts, or its seas, its vegetation, or the vapors rising into its atmosphere are chiefly clothed with this shade. Nevertheless, the poles always preserve their brilliant light. An ancient philosopher, Anaxagoras, stated that snow was black: his paradox had been somewhat smoothed or cleared if the snows of Mars, each time that we were able to perceive them distinctly, had been red; but they are white also. "The color of the polar markings," said Beer and Mädler, two astronomers whose lives have been devoted to the study of Mars and the Moon, "is always of a bright and pure white, in no way similar to the color of the other parts of the planet. In 1837 it once happened that Mars was, during the observations, completely darkened by a cloud, with the exception of the poles which stood out distinctly."

Moreover, is the water of Mars the same as the water on the Earth? Father Kircher was asked if that of Venus would be good for baptizing; and it was not doubted. We ask ourselves whether there are the same chemical elements as there are here, and we doubt it. That the polar markings of Mars are masses of ice and snow seems proved by observation, as the changes which they undergo annually are occasioned, as with us, by the apparent movement of the Sun This fact has been abundantly proved. When a snow zone is of large extent, it is after the long winter of the pole to which it belongs; when the same spot is very small, it is after a summer which has melted and successively contracted it. But from this it must not be concluded that the term snow signifies anything but an appearance, and there is no plausible proof to be relied on that the substance that we know under the name of snow is actually seen there—that is to say, water (chemically, an equivalent of hydrogen and oxygen: H_2O) frozen into small needles. It is, on the other hand, possible that the constituent elements of the globe of Mars are very different from those with which the Earth is formed, and their chemical combinations having been from the beginning submitted to other influences than those which are at work on our globe, there may exist but a remote analogy between the nature of this world and our own, and not an identity of matter.

Removed from the Sun to a mean distance of 139 millions of miles, and encircling the Earth's orbit in that which it describes round the central body, there are certain periods when these two planets are very near together; that is, when they are both on the same side of their path with regard to the Sun. Sometimes they are not more than 48 millions of miles distant from each other. It is this which makes Mars, after the Moon, best known to us, so that Kepler was able to say: "It is from the knowledge of Mars that astronomy will reach us, and it is from the study of this planet that the future progress of our science will advance."

The conjunction of two planets is the point of their orbits where they are on the same side of the Sun, and are the nearest possible to each other; the term opposition is given to the opposite point of their paths, when they are on opposite sides of the Sun, except in the case of Mercury and Venus. In olden times these positions greatly exercised the sagacity of horoscope-seekers, and Heaven knows how many destinies have received fancied predictions, according as the god of war was in conjunction in such and such sign of the zodiac. The conjunction in the Bull was not at all the same as that which happened in the Virgin; and when by chance it had the misfortune to occur in the Goat, the most learned were lost in conjectures on the bad fortune predicted to the new-born. The interior planets, Venus and Mercury, whose orbits are inclosed in that of the Earth, have no opposition, but they have two conjunctions; the superior, when the planet is beyond the Sun and in one right line; the inferior, when it is situated between the Sun and the Earth. The exterior planets, those which inclose the terrestrial orbit, and of which Mars is the first, have only the superior conjunction.

At about 80 millions of miles, beyond the planet Mars, between the orbit of this planet and that of Jupiter, we meet with the group of small planets, of which we have already spoken. These are very little worlds, if even they deserve this name, which have scarcely the extent of a province, or even a department. They gravitate in his zone in considerable numbers, for there may exist several thousands. Already 109 have been discovered: the first in 1801 and the last in 1870 Perhaps they are *débris* of a larger world shattered by some catastrophe; perhaps they have been formed in this region of space in the fragmentary state in which we now see them. This is not decided, seeing that science now, as in the time of Virgil, is not yet able to determine on the origin of things.

"Felix qui potuit rerum cognoscere causas."

Putting aside the title of original greatness of these asteroids, and the fate which attends them, let us traverse their colony, and beyond it get near the most magnificent of the worlds of our system.

VII.

JUPITER.

The orb of Jupiter is more bulky than all the other planets of our system: it is only a thousand times smaller than the Sun, which makes it, if we remember the volume of that radiant body, from fourteen to fifteen hundred times larger than the terrestrial

globe. Also, although it revolves in an orbit nearly 475 millions of miles distant from the Sun, and receives a much fainter light than that received by the Earth, its size is evidenced by the light with which it shines during our starry nights, equal and often superior to that with which Venus shines. Jupiter is therefore reckoned among the most beautiful objects of the heavens. As it is always in the zodiac, and when Venus is visible in the evening it is always in the west, it is easily recognized. At whatever period of the year, therefore, you see a very bright star, either in the east or high up among the zodiacal constellations, you may be certain that it is Jupiter.

This planet is a charming one, so far at least as we are able to judge from afar and without going there. To begin with, a continual spring rejoices its surface. If it is ornamented with flowers, which we do not doubt, though we know not of what these flowers consist, they do not only survive "the span of a morning" as our roses do, but live much longer. Scarcely have the oldest begun to dry up and fade but they are replaced by lovely buds, opening before the first have died away. Not only is the Jovian year equal to twelve of ours, but it is scarcely known when the yearly period begins or ends. No winters, no summers, always spring.

Then Jupiter, as I have stated, presents a surface 126 times more extensive than the terrestrial surface. I speak of surface, not volume. Now, a hundred and twenty-six Earths placed side by side, and on which the human race would be able to spread itself at will, would constitute a very fine country. We ought, then, not to doubt that such an empire has been formed to serve as an abode for a human family, venerable and worthy of our respect. We reason thus *apropos* of Jupiter because we have had the necessary means to measure and appreciate it at its just value. But it is necessary to add something to complete the comparison between this world and our own.

Because we find, by observation of the Jovian planet, excellent reasons for believing that its inhabitants are very favored, it does not follow that the aforesaid inhabitants make similar reflections on us. There is a very good reason why they do not occupy themselves with us—they are probably not acquainted with our existence. And, indeed, if ever, at a future time, more or less distant, you should happen to inhabit Jupiter, you would have great trouble to discover your old country. To do so you would have to rise a little before the Sun (and mark, there are only five hours from the setting to the rising of this body on Jupiter) and five or six minutes before the rising look to the east for a very small white star. With good eyes you perhaps would perceive it. In this case you would know that our Earth exists. Again, you would make the same search six months later, at the west, a few moments after the setting of the Sun. Such is the condition of the inhabitants of Jupiter with regard to us. They can never see the Earth during the night, although it is precisely in the middle of clear nights that we are best able to observe this magnificent planet.

No. Jupiter is an earth, a splendid earth, compared to which ours is only a moon.

If we were allowed to observe Jupiter closely and to accustom ourselves to its nature, to live for some time in the midst of its train, and to appreciate all its importance, we should think our globe very small after such a stay. We should be like the good villagers who came once in their life to see Paris, and who, if they had the misfortune to remain there only a month, could not even think of their village ; it became eclipsed by the single remembrance of the splendor they had glanced at.

VIII.

SATURN.

If you happen one day to take a little journey to the planet Saturn, which is scarcely more than 900 millions of miles from us, you would feel on approaching it an unspeakable astonishment, to which certainly no sentiment of surprise felt on the Earth can be compared. Imagine an immense globe, not only of the size of the Earth, but as large as 734 Earths put together. It revolves on an axis with such rapidity that, in spite of its size, it accomplishes its diurnal rotatory movement in about ten hours. Around it, at 20,000 miles distance, above its equator, an immense ring, flat and relatively very thin, surrounds it on all sides. This ring is followed by a second, and this one by a third. Now this system of multiple rings is only a few miles thick, while its diameter is 166,000 miles. They do not remain immovable, but are carried along with a circular movement round the planet, this movement being of still greater rapidity than that of the planet itself. The domain of the Saturnine world is not confined to this. Beyond the ring eight moons are seen revolving in the heavens around this strange system ; the nearest of these satellites is separated from the planet's centre by a distance of 120,000 miles ; the most remote has an orbit of 2,293,-

Fig. 28 —Saturn and its Satellites.

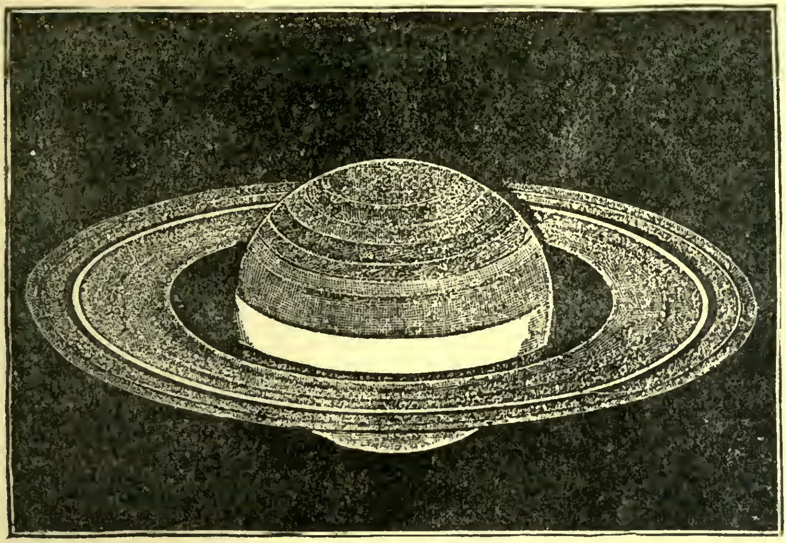


Fig. 29.—Saturn.

,00 miles from the centre of the planet. Saturn, then, governs a system which measures not less than four and a half millions of miles in diameter.

By the side of this world the Earth makes but a poor figure, and Micromegas was to be pardoned when, on coming out of Saturn, he mistook the Earth for a molehill. Its years are thirty times longer than ours ; of its seasons each lasts seven years and four months ; a change remarkably like that which distinguishes our own diversifies them ; a regenerating spring succeeds the rigor of winter ; summer and autumn pour forth their alternate fruits. But the phenomenon which draws most attention to this world is that gigantic ring which surrounds it. It was long before astronomers were able to give any account of this singular appendage in the planetary system.

Galileo, who first saw on each side of Saturn something bright of which he could not distinguish the form, was greatly astonished with such an aspect. He first announced it under an anagram, in which Kepler himself could not discover anything, and, as he had done with Venus, disguising his discovery, he gave himself time to bring it to perfection. He called it three-bodied, for want of better knowledge. "When I observe Saturn," he wrote later to the ambassador of the Grand Duke of Tuscany, "the central star appears the largest ; two others, situated, one to the east, the other to the west, and on a line which does not coincide with the ecliptic, seem to touch it. They are like two servants who enable old Saturn to continue his road, and they remain always at his side. With a glass of small power the star appears lengthened and of an olive form."

The laborious astronomer sought in vain ; he was not favored in his researches as in the preceding ones. At the period when the edges of Saturn's rings are presented to us, they disappear on account of their thinness. Galileo, finding on a certain night the absolute impossibility of distinguishing anything on either side of the planet, where, a few weeks before, he still observed the two luminous objects, was completely in despair ; he came to the belief that his glasses had misled him. Being entirely discouraged, he no longer observed Saturn, and died without knowing that the ring existed. In the same way, later, Hevelius declared he was puzzled, and it was not until 1659 that Huygens, the real author of the discovery of the ring, made the first satisfactory observation and explained its structure. With the contemporaries of Galileo, Saturn was considered to be a bowl with handles, or a cardinal's hat. In the middle of the eighteenth century Maupertuis conjectured that the ring was only a comet's tail, wound like a turban round the Saturnian globe. Toward the end of the same century Du Séjour wrote his "Essai sur les phénomènes relatifs aux disparitions périodiques de l'anneau de Saturne," in which he found, theoretically, the time of rotation of the ring ; he presented his work to Voltaire with the following graceful dedication :

"Monsieur, accept, I pray you, the history of a respectable old man, with whom they will busy themselves on the earth, whilst to know him will be an honor among men ; his forehead is wreathed with an immortal crown ; he shines on us, and presents one of the most singular phenomena of nature. This aged person is Saturn. I hasten to name him lest he have another given him, which your modesty would

prevent you from recognizing. May this analogy gain for my work a favorable reception from you!"

Without the last remark, Voltaire himself, and sooner than any one else, might have thought that Saturn had very little to do with the dedication. At this time Saturn's system included, besides its rings, five satellites revolving round it. Since that time three others have been added, and the cortége is composed of eight members. The following table shows the order of their distances from the planet, their names, the order of their discovery, the discoverers, and date of the discoveries:

1. Mimas	Herschel	1789
2. Enceladus	Herschel	1789
3. Thetis	Cassini	1684
4. Dione	Cassini	1684
5. Rhea	Cassini	1672
6. Titan	Huygens	1655
7. Hyperian	Bond and Lassell	1848
8. Japhet	Cassini	1671

Saturn has not been favored by ancient poets, who did not guess at its grandeur and richness. Situated at the extreme limit of the planetary system, and marking the frontier until the period of the discovery of Uranus, he was considered as the coldest and slowest of all bodies. It was the god of Time, dethroned and banished in a sort of exile. Misfortune to those who were born under its influence! If, at the moment of birth, it was in the zodiacal sign of the month, the newly-born had nothing more to ask than to go again into nothingness. For a thousand years a considerable number of serious men had full and entire faith in horoscopy, themselves deceived through ignorance and often in sincerity. These ideas, happily having given way before the light of science, are too curious for me not to give a slight specimen. Hear, for example, an astrologer, who wrote, in 1574, the following absurdities:*

"Saturn is in the seventh heaven. He makes rustics; signifies peasants, laborers, and mercenaries; makes thin, solitary, and dreamy people, who, when walking, keep their eyes to the ground; it also signifies stooping, old people, Jews and beggars, mechanics and people of low condition, and causes death, ice, and epidemics; in short, it has no light except that which others impart to it." So much for the conditions; but this is as nothing to the influence of this unfortunate on diseases.

"Saturn," says La Martinière, "is a dull, dry, nocturnal, and malevolent planet, to whom are attributed long, quartan, or daily fevers, indispositions of the tongue, arms, and bladder, general paralysis, gouts, abscesses, obstructions of the heart and spleen, the black jaundice, polypus, diseases of the intestines—such as windy colics, piles, hemorrhoids, hernia, corns on the feet, spitting of blood, canine appetite, difficulty of breathing, stones in the loins and bladder, epilepsy, cachexy, dropsy, melancholy, leprosy, and other diseases proceeding from foul and putrefying humors . . . (all cannot be quoted). Those who are born in its season are melancholy and phlegmatic." Saturn has no idea of having caused such misfortunes to the inhabitants of the earth. Let us hope, for our reputation there, that astrologers in Saturn will not have used reprisals; for, then, of what sorcery will they not accuse us? But we have good reason for believing that we are not viewed ill by the Saturnians; for this reason (which, however, does not do us great honor), that from Saturn they do not see the Earth, as our globe is too small, and is hidden by the Sun.

According to a still more singular author, the devil may be made to appear to us, by invoking him, on the Sabbath-day. Saturday, consecrated to Saturn by a cabalistic formula, extremely long and difficult to pronounce, and by presenting to Saturn a perfume composed as follows: "Mix the seed of poppy and henbane, mandrake-root, powdered loadstone, and good myrrh; reduce these drugs to fine powder, and mix them with some blood of bats and brain of black cats," etc. I will not give the whole, lest you might try the recipe.

Each planet influenced the destinies of men, according to the date of their birth. Thus in the first sign of the zodiac, "Jupiter made bishops, prelates, nobles, powerful people, judges, philosophers, wise men, merchants, and bankers. Mars signified warriors, firebrands, murderers, doctors, barbers, butchers, goldsmiths, cooks, bakers, and all trades having to do with fire. Venus produces queens and beautiful women, apothecaries (how well that follows!), tailors, workers in jewels and ornaments, cloth-merchants, gamesters, those who frequent public-houses, those who play with thimbles, libertines, and brigands. Mercury produces clerks, philosophers, astrologers, geometers, arithmeticians, Latin authors, painters, ingenious and cunning workmen, both men and women, and their arts."

Mars may be compared to Saturn for the bad reputation given to it by astrologers. The following sentence will suffice to show this: "People over whom Mars presides are rough, rude, and invincible, and can be prevailed upon by no reason; they are obstinate, quarrelsome, rash, daring, violent, and accustomed to be deceived by report; gluttons, digesting various meats; strong, robust, imperious; with bloodshot eyes, red hair, not possessing affection toward their friends, but exercising the arts of fire and sword; in short, Mars generally produces furious, quarrelsome, dissolute, self-conceited and choleric men."

As to Venus, no star has had such a favorable influence. It is useless to state in what its action chiefly consisted; but it appeared that those over whom it presided were most happy mortals. These odd and erroneous ideas on a pretended influence of the planets, and all those which constituted the vast astrological domain, arose from man's super-

* La Taille de Boudaroy, *Géomancie abrégée.*

stition, which is always attracted toward the wonderful, and his pride, which represented the universe as formed expressly for him. As long as the old system of the world, founded on appearances, reigned, man was a prey to this morbid error. The torch of true science—of science founded on discussed observations and calculation—was alone capable of bringing light into the midst of this darkness, and dissipating it in proportion as man shall rise more in true knowledge. It will be a more glorious title of honor for the centuries which are to come, to have delivered the human mind from these illusions, and forever to have triumphed over them. Often, in those times when man's life was so easily sacrificed, astrologers, alchemists, and sorcerers were burned alive, hung, broken on the wheel, beheaded, quartered, or executed by long tortures, for having predicted badly. I could point out hundreds of sorcerers burned for pretended witchcraft, or for profanations which arose rather from their credulity than their wickedness; astrologers hung or drowned according to the good pleasure of princes; seekers of the philosopher's stone executed for having made a compact with the devil; but this is not the place; and in speaking of astrology in this chapter on Saturn, I have only wished to profit by the circumstance to show once again what benefits we owe to science, and to what depths man could again fall if ever the torch of science were extinguished. Saturn's world deserves something better from our hands. Not only do we deny the sinister influences of which he is the supposed author, but again we admire in him a magnificent abode of life, in the midst of which the forces of nature continue under aspects which are still unknown to us. Amid his splendid rings, and rich system of eight moons, he reigns peacefully in the heavens; and we love to contemplate his venerable figure, in those distant regions, as the type of a creation already advanced in that era of perfection to which all beings aspire. This disquieting Saturn has not always been treated with more respect by the moderns than by the ancients; has it, in its turn, a bad star? Some people still regard it with an evil eye—for instance, the author of the "Contemplations" made it the place of chastisement of wicked souls, while the happy ones passed from sphere to sphere.

This would be hateful! Let us hope that there are in this picture reminiscences of the ancient ideas on Saturn, and that this globe is less frightful than it looks to the prejudiced. This strange world does not want for riches; and if we were able one day to visit it, doubtless we should find it much more beautiful than the Earth, and we should vow henceforth to reside in such a royal and majestic domain.

Saturn, in the eyes of the ancients, kept the frontier of the solar empire, of which the composing Seven would not see their number increased. Science, daring and independent, which despises opinions and prejudices, has without scruple passed this barrier and discovered two new worlds, which extended the ramparts of the solar domain three times beyond their old position.

IX.

URANUS.

On the 13th of March, 1781, between ten and eleven in the evening, a quondam organist of Halifax, who had himself made the best telescope then in existence, observed the small stars of the constellation of the Twins, with a telescope of nine feet focal length, and a magnifying power of 227. During his observation he perceived that one of the stars presented an unusual diameter. Astonished, and desiring to prove the fact, he took an eyepiece magnifying double, and found that the diameter of the star increased while that of the others remained the same. More and more surprised, he fetched his magnifying power of 932, being quadruple that of the first, and again observed it. The mysterious star was still larger. From that time he no longer doubted; this was a new body, not a star. He continued the following days, and noticed that it slowly moved among the others. It was, then, a comet. Herschel described it to the Royal Society in a paper entitled, "Account of a Comet;" and the scientific world of all countries registered this new cometary body, and set about observing it in order to determine its orbit.*

The name of the astronomer was then so little known that it is found written in every way: Mersthel, Herthel, Hermstel, Horochelle, etc. Nevertheless, the discovery of a new comet was an event important enough to induce a study of the new body. Laplace, Méchain, Boscowich, and Lexell endeavored to determine the orbit along which it moved. Many months elapsed before they guessed that it was a real planet and it was not until after having observed that all the imagined orbits for the pretended comet were soon contradicted by observation, and that it probably had a circular orbit, much more distant from the Sun than Saturn, until then the boundary of the system, that they agreed to regard it as a planet. Still this was but a provisional agreement.

It was, indeed, more difficult than was thought thus to increase unscrupulously the family of the Sun. Many reasons of propriety were opposed to it. Old ideas are tyrannical. It had been the custom for so long to regard the venerable Saturn as keeper of the frontiers, that it required a great effort to determine upon withdrawing these frontiers and guarding them by a new world. It happened in this as in the discov-

* "If Herschel had directed his telescope toward the constellation of the Twins eleven days sooner," said Arago, "the real movement of Uranus would have escaped him, for this planet was on the second at one of its stationary points." It may be seen by this remark on what the greatest astronomical discoveries depend.

ery of the small planets situated between Mars and Jupiter. Two years before this discovery was made, Kepler imagined, for the harmony of the world, a large planet in this space, and the most frivolous and senseless considerations were urged against it. For instance, they reasoned: "There are only seven openings in the head, the two eyes, the two ears, the two nostrils, and the mouth; there are only seven metals; there are but seven days in the week; therefore there are but seven planets," etc. Considerations like these, and others no less imaginary, often hinder the progress of astronomy.

When William Herschel, having been present as a spectator at the debates created by his discovery, came to the belief that his comet was a planet, situated at the confines of our system, he claimed the right, which was indisputably his, of christening the new star. Animated by a lawful motive of gratitude toward George III., who had appreciated his astronomical worth and given him an annual pension, he at first proposed the name of Georgium Sidus, George's star, as Galileo had called the satellites of Jupiter discovered by him, the Medici's stars, and as Horace had said, Julium Sidus. Others proposed the name of Neptune, in order to preserve the mythological character; Saturn would be thus found between his two sons, Jupiter and Neptune. Others added to Neptune the name of George III.; others again proposed Astræa, considering the goddess of Justice was as far as possible from the Earth; Cybele, mother of the gods; Uranus, the most ancient of all to whom reparation was due after so many hundred years of neglect. Lalande suggested Herschel's name, to immortalize the discoverer. These two denominations prevailed. For a long time the planet bore the name of Herschel, but custom has since declared for the mythological appellation of Uranus.

The discovery of Uranus has increased the radius of the solar system from 872 millions of miles to 1753 millions.

Compared with the preceding, this planet is not very large, for it is scarcely eighty-two times more bulky than the Earth. Its seasons last twenty-one years, and its years eighty-four years and a quarter. Around it revolve eight satellites, six of which Herschel himself discovered. These eight moons are rather curious, for instead of revolving from west to east like all moons and planets of the system, they go from east to west, and, moreover, travel at a singularly decided inclination. The reason of this no one can tell.

It was thus, at the period when European society felt the first miseries of the Revolution which was near, that Science with peaceful conquests saw its glory increase, and visited new skies.

X.

NEPTUNE.

THE world which here marks the frontiers of the system is situated at such a distance from the Sun that the light and heat which it receives from it are thirteen hundred times less than that with which the Earth is enriched, so that no great difference can be noticed between the day and night of this distant planet, and to it the solar disk is nearly reduced to the smallness of the stars. Hence it follows that at its surface the stars of the heavens remain visible in the day as well as in the night, and that the Sun is only a more brilliant star than the others. From Neptune, then, the eye, situated between the planetary world and the starry heavens, is in a region where it must be much more sensitive and endowed with peculiar properties, which permit it to especially appreciate the sidereal world and its riches.

2746 millions of miles is the distance which separates this world from the Sun. Until the time of its discovery, the frontiers of the planetary system, already augmented by the addition of Uranus, were confined to an orbit of 1753 millions of miles in radius. Does this, then, imply that these are the utmost limits, and that analysis will not be able to go farther and add fresh members to the already increasing family of the Sun? No. When observations spreading over a long series of years shall have been made, and compared with each other, the universal law of gravitation by which the existence of this planet was known before ever being perceived in the field of the telescope, will prove the existence of others, if others exist, which is probable; and the progress of optics following equally the progress of astronomy will give to the visual power, again magnified, the power to discover such distant planets, which will, doubtless, be of the sixteenth or seventeenth magnitude.

Imagine a body a hundred times larger than the Earth carried into the gloomy deserts of space to the distance of the Neptuian orbit. It floats isolated, in the obscurity of space, following an immense but purely ideal curve, and which exists only in theory in the decree of eternal laws. It follows this curve, and revolves on itself without ever deviating from its path. To finish its immense route and return to its starting, point, it requires 164 years. It will return and again pass through this mysterious point of space, which it passed nearly two centuries before. What power moves it? What hand guides this blind body through the night of the distant regions, and what causes it to describe this harmonious curve? It is universal attraction.

Instead of following a regular ellipse round the Sun, the planet Uranus underwent, from some unknown cause, a perturbation, which retarded its theoretical path, and extended its circular curve toward a certain point, as if an attractive cause had seduced the traveller from its path, and had made it deviate from its proposed route. It was calculated that, in order to produce at this point an attraction of such intensity, it was necessary that there should be on that side

of the system beyond Uranus, a planet of a certain mass, and at a certain distance. Two astronomers, the one French, the other English, set to work at the same time in this research. They discovered the disturbing cause theoretically, and observers directed their telescopes to the spot thus indicated by theory. They were not long in actually discovering the body near the spot pointed out, and they were able to announce to the world the most brilliant confirmation of universal gravitation.

The distance of this planet had been theoretically deduced from a well-known empirical law called "Bode's Law," which, however, was first given out by Titius. It is as follows. Starting from 0 put down the number 3, and double successively, thus:

0 3 6 12 24 48 96 192 384

Add four to each of these numbers:

4 7 10 16 28 52 100 196 388

Now, it happens that these numbers represent the successive distances of the planets from the Sun, even of the small planets, which were not known at the time this law was promulgated for the first time. The orbit of Mercury is expressed by the number 4; that of Venus by 7; the Earth by 10; Mars by 16; 28 describes the mean orbit of the asteroids. Jupiter's is expressed by 52; Saturn's by 100; and Uranus' by 196. According to this there seemed a legitimate right to place the new planet at the distance of 388. Now the real distance of Neptune is only 300; and it is to this irregularity of the series starting from Uranus that we must attribute the disagreement which exists in reality between the elements of the theoretical prediction of Neptune and those given by ulterior observation.

It must be remembered that this formula is not, like that of attraction, the expression of the intimate force which governs the spheres. After Kepler had recognized the three fundamental laws which we have before announced, Newton discovered the mode of action of this universal force, to which we owe the stability of the world. "Bodies attract each other according to their masses, and in the inverse ratio of the square of their distances." In the immensity of the vast heavens, the gigantic suns of space obey this formula, and in the littleness of the actions which are performed on the surface of the Earth, the mechanical functions of small beings do not escape its rule. It is the law of creation, sustaining the life of the edifice in the invisible as in the vast. "Attraction," says the author of "Paul and Virginia," "is a harmonious lyre, which resounds under divine fingers."

When we contemplate these harmonious movements of the spheres in their orbits, in the system confided to the keeping of the Sun; when we have seen that these formidable laws regulate the movements of stellar systems with the same sovereignty as they direct those which are executed around us, and when to this marvellous grandeur of the laws of nature we compare human weakness and our insignificance in the midst of this sublime creation, we sincerely admire the genius of the men which rose to the idea of these causes: it seems that their power spreads itself to other men, and one feels proud of belonging to humanity.

XI.

COMETS.

These tailed bodies, which suddenly come to light up the heavens, were for long regarded with terror, like so many warning signs of divine wrath. Men have always thought themselves much more important than they really are in the universal order; they have had the vanity to pretend that the whole creation was made for them, while in reality the whole creation does not suspect their existence. The Earth we inhabit is only one of the smallest worlds; and therefore it can scarcely be for it alone that all the wonders of the heavens, of which the immense majority remain hidden from it, were created. In this disposition of man to see in himself the centre and the end of everything, it was easy indeed to consider the steps of nature as unfolded in his favor; and if some unusual phenomenon presented itself, it was considered to be without doubt a warning from Heaven. If these illusions had had no other result than the amelioration of the more timorous of the community, one would regret those ages of ignorance; but not only were these fancied warnings of no use, seeing that, once the danger passed, man returned to his former state; but they also kept up among people imaginary terrors, and revived the fatal resolutions caused by the fear of the end of the world.

When one fancies the world is about to end—and this has been believed for more than a thousand years—no solicitude is felt in the work of improving this world; and, by the indifference or disdain into which one falls, periods of famine and general misery are induced which at certain times have overtaken our community. Why use the wealth of a world which is going to perish? Why work, be instructed, or rise in the progress of the sciences or arts? Much better to forget the world, and absorb one's self in the barren contemplation of an unknown life. It is thus that ages of ignorance weigh on man, and thrust him farther and farther into darkness, while Science makes known, by its influence on the whole community, its great value, and the magnitude of its aim

The history of a comet would be an instructive episode of the great history of the heavens. In it could be brought together the description of the progressive movement of human thought, as well as the astronomical theory of these extraordinary bodies. Let us take, for example, one of the most memorable and best-known comets, and give an outline of its successive passages near the Earth. Like the planetary worlds, Comets belong to the solar system, and are subject to the rule of the Star King. It is the universal law of gravitation which guides their path; solar attraction governs them, as it

govern the movement of the planets and the small satellites. The chief point of difference between them and the planets is that their orbits are very elongated; and, instead of being nearly circular, they take the elliptical form. In consequence of the nature of these orbits, the same comet may approach very near the Sun, and afterward travel from it to immense distances. Thus, the period of the Comet of 1680 has been estimated at 3000 years. It approaches the Sun, so as to be nearer to it than our Moon is to us, while it recedes to a distance 853 times greater than the distance of the Earth from the Sun. On the 17th of December, 1680, it was at its perihelion—that is, at its greatest proximity to the Sun; it is now continuing its path beyond the Neptunian orbit. Its velocity varies according to its distance from the solar body. At its perihelion it travels thousands of leagues per minute; at its aphelion it does not pass over more than a few yards. Its proximity to the Sun in its passage near that body caused Newton to think that it received a heat 28,000 greater than that we experience at the summer solstice; and that this heat, being 2000 times greater than that of red-hot iron, an iron globe of the same dimensions would be 50,000 years entirely losing its heat. Newton added that in the end comets will approach so near the Sun that they will not be able to escape the preponderance of its attraction, and that they will fall one after the other into this brilliant body, thus keeping up the heat which it perpetually pours out into space. Such is the deplorable end assigned to comets by the author of the "Principia," an end which makes De la Bretonne say to Rétif: "An immense comet, already larger than Jupiter, was again increased in its path by being blended with six other dying comets. Thus displaced from its ordinary route by these slight shocks, it did not pursue its true elliptical orbit; so that the unfortunate thing was precipitated into the devouring centre of the Sun." "It is said," added he, "that the poor comet, thus burned alive, sent forth dreadful cries!" It will be interesting, then, in a double point of view, to follow a comet in its different passages in sight of the Earth. Let us take the most important in astronomical history —the one whose orbit has been calculated by Edmund Halley, and which was named after him. It was in 1682 that this comet appeared in its greatest brilliancy, accompanied with a tail which did not measure less than 32 millions of miles. By the observation of the path which it described in the heavens, and the time it occupied in describing it, this astronomer calculated its orbit, and recognized that the comet was the same as that which was admired in 1531 and 1607, and which ought to have reappeared in 1759. Never did scientific prediction excite a more lively interest. The comet returned at the appointed time; and on the 12th of March, 1759, reached its perihelion. Since the year 12 before the Christian era, it had presented itself twenty-four times to the Earth. It was principally from the astronomical annals of China that it was possible to follow it up to this period.

Its first memorable appearance in the history of France is that of 837, in the reign of Louis le Débonnaire. An anonymous writer of chronicles of that time, named "The Astronomer," gave the following details of this appearance, relative to the influence of the comet on the imperial imagination:

"During the holy days of the solemnization of Easter, a phenomenon ever fatal, and of gloomy foreboding, appeared in the heavens. As soon as the Emperor, who paid attention to these phenomena, received the first announcement of it, he gave himself no rest until he had called a certain learned man and myself before him. As soon as I arrived, he anxiously asked me what I thought of such a sign. I asked time of him, in order to consider the aspect of the stars, and to discover the truth by their means, promising to acquaint him on the morrow; but the Emperor, persuaded that I wished to gain time, which was true, in order not to be obliged to announce anything fatal to him, said to me. 'Go on the terrace of the palace and return at once to tell me what you have seen, for I did not see this star last evening, and you did not point it out to me; but I know that it is a comet; tell me what you think it announces to me.' Then scarcely allowing me time to say a word, he added: 'There is still another thing you keep back: it is that a change of reign and the death of a prince are announced by this sign.' And as I advanced the testimony of the prophet who said, 'Fear not the signs of the heavens as the nations fear them,' the prince, with his grand nature, and the wisdom which never forsook him, said, 'We must only fear Him who has created both us and this star. But as this phenomenon may refer to us, let us acknowledge it as a warning from Heaven.'"

Louis le Débonnaire gave himself and his court to fasting and prayer, and built churches and monasteries. He died three years later, in 840, and historians have profited by this slight coincidence to prove that the appearance of the comet was a harbinger of death. The historian, Raoul Glaber, added later: "These phenomena of the universe are never presented to man without surely announcing some wonderful and terrible event."

Halley's comet again appeared in April, 1066, at the moment when William the Conqueror invaded England. It was pretended that it had the greatest influence on the fate of the battle of Hastings, which delivered over the country to the Normans.

A contemporary poet, alluding probably to the English diadem with which William was crowned, had proclaimed in one place, "that the comet had been more favorable to William than nature had been to Cæsar; the latter had no hair, but William had received some from the comet." A monk of Malmesbury apostrophized the comet in these terms: "Here thou art again, thou cause of the tears of many mothers! It is long since I have seen thee, but I see thee now, more terrible than ever; thou threatenest my country with complete ruin!"

In 1455 the same comet made a more memorable appearance still. The Turks and Christians were at war, the West and the East seemed armed from head to foot—on the point of annihilating each other. The crusade undertaken by Pope Calixtus III. against the invading Saracens was waged

with redoubled ardor on the sudden appearance of the star with the flaming tail. Mahomet II. took Constantinople by storm, and raised the siege of Belgrade. But the Pope having put aside both the curse of the comet and the abominable designs of the Mussulmans, the Christians gained the battle, and vanquished their enemies in a bloody fight. The *Angelus* to the sound of bells dates from these ordinances of Calixtus III. referring to the comet.

This ancient comet witnessed many revolutions in human history, at each of its appearances, even in its later ones; in 1682, 1759, 1835, it was also presented to the Earth under the most diverse aspects, passing through a great variety of forms, from the appearance of a curved sabre, as in 1456, to that of a misty head, as in its last visit. Moreover, this is not an exception to the general rule, for these mysterious stars have had the gift of exercising a power on the imagination which plunged it in ecstasy or trouble. Swords of fire, bloody crosses, flaming daggers, spears, dragons, fish, and other appearances of the same kind, were given to them in the middle ages and the Renaissance.

Comets like those of 1577 appear, moreover, to justify by their strange form the titles with which they are generally greeted. The most serious writer were not free from this terror. Thus, in a chapter on celestial monsters, the celebrated surgeon Ambroise Paré described the comet of 1528 under the most vivid and frightful colors: "This comet was so horrible and dreadful that it engendered such great terror to the people that they died, some with fear, others with illness. It appeared to be of immense length, and of blood color; at its head was seen the figure of a curved arm, holding a large sword in the hand, as if it wished to strike. At the point of the sword there were three stars, and on either side were seen a great number of hatchets, knives, and swords covered with blood, among which were numerous hideous human faces, with bristling beards and hair." The imagination has good eyes when it exerts itself. The great and strange variety of cometary aspects is described with exactitude by Father Souciet in his Latin poem on comets. "Most of them," says he, "shine with fires interlaced like thick hair, and from this they have taken the name of comets. One draws after it the twisted folds of a long tail; another appears to have a white and bushy beard; this one throws a glimmer similar to that of a lamp burning during the night; that one, O Titan! represents thy resplendent face; and this other, O Phebe! the form of thy nascent horns. There are some which bristle with twisted serpents. Shall I speak of those armies which have sometimes appeared in the air? of those clouds which follow as it were along a circle, or which resembled the head of Medusa? Have there not often been seen figures of men or savage animals?

"Often, in the gloom of night, lighted up by these sad fires, the horrible sound of arms is heard, the clashing of swords which meet in the clouds, the ether furiously resounding with fearful din which crush the people with terror. All comets have a melancholy light, but they have not all the same color. Some have a leaden color; others that of flame or brass. The fires of some have the redness of blood; others resemble the brightness of silver. Some again are azure; others have the dark and pale color of iron. These differences come from the diversity of the vapors which surround them, or from the different manner in which they receive the Sun's rays. Do you not see in our fires, that various kinds of wood produce different colors? Pines and firs give a flame mixed with thick smoke, and throw out little light. That which rises from sulphur and thick bitumen is bluish. Lighted straw gives out sparks of a reddish color. The large olive, laurel, ash of Parnassus, etc., trees which always retain their sap, throw a whitish light similar to that of a lamp. Thus, comets whose fires are formed of different materials, each take and preserve a color which is peculiar to them."

Instead of being a cause of fear and terror, the variety and variability of the aspect of comets ought rather to indicate to us the harmlessness of their nature.

XII.

COMETS (CONTINUED).

The following are some of the ideas put forth by Maupertuis in his "Lettres sur la Comete de 1742":

In the present day it will not be believed that such distant bodies as comets can have any influence on things here below, nor can they be signs of what is to happen. What connection should these bodies have with that which goes on in the councils and armies of kings?

It would be necessary that their influence should be made known, either by revelation, reason, or experience; and it may be said that we have not met with it in any of these sources of our knowledge. It is very true that there is an universal connection between everything in nature, as much in the physical as in the moral world; each event, bound to that which precedes it, and to that which follows it, is only one link of the chain which forms the order and succession of things; if it were not placed as it is, the chain would be different, and would belong to another universe.

Reasoning thus, the astronomer doubts the non-influence of comets as well as he does their influence; to confirm his ideas, he recalls those of others, and soon comes to the belief that comets cause many other events besides simple colds.

Kepler, to whom astronomy owes so much, thought it reasonable that, as the sea has its whales and its monsters, the air possesses them also. These monsters are comets, and he explains how they are produced.

Some people have believed that comets were expressly created every time it was necessary to announce the design of God to men, and that the angels had the care of them. They added that this explanation solved all the difficulties which could arise in the matter. Lastly, in order that all the absurdities with regard to them may be stated, there were some people who denied that comets existed, and who considered them as false appearances, caused by the reflection or refraction of light. They alone understood how the reflection or refraction was caused, without bodies to cause it. According to Aristotle, comets were meteors formed by exhalations from the earth and sea, and this was, as may be imagined, the decision of the crowd of philosophers who believed and thought only as he did. In older times still, people possessed more correct ideas of comets. The Chaldeans knew that they were material bodies and a species of planet, the courses of which they succeeded in calculating. Seneca embraced this opinion; he speaks to us of comets in a manner so conformable with all that is known of them in the present day, that it may be said that he guessed what the experience and observations of moderns have discovered.

It was after having spoken of the opinions of the ancients that Maupertuis explained his own. "The regular course of comets no longer allows them to be considered as warnings, or as lighted torches to terrify the Earth. But although a more perfect knowledge than that which the ancients had prevents us from regarding them as supernatural warnings, it teaches us that they may be the physical causes of great events." He dreads the approach of the tailed bodies to the Earth. In the variety of their movements he sees the possibility o an encounter with some planets, and, consequently, with the Earth. It cannot then be doubted, says he, that terrible accidents will happen from the simple approach of these two bodies, for such approach would make great changes in their movements, either because of the attraction which they exercise over each other, or because of some fluid confined between them. The least of these movements would do nothing less than change the situation of the axis and poles of the Earth. That part of the globe which was formerly toward the equator would be found, after such an event, near the poles, and that which was near the poles would be found toward the equator. "The approach of a comet," he adds, "might have other still more frightful consequences. I have not yet spoken to you of the tails of comets. On these, as on comets, strange opinions have been held; but the most probable is that they are principally composed of immense torrents of exhalations and vapors, which the Sun's heat draws from their nuclei. A comet, accompanied by a tail, may pass so near the Earth that we may find ourselves immersed in the torrent which it carries with it."

Such is the perspective to which we are by degrees conducted by this physicist; but he gives us a singular consolation. As the human race would all perish together in this catastrophe, being swallowed up by boiling water, or poisoned by mephitic gases, and as no one would remain to weep over the agony of the Earth, he tells us it is easy to console ourselves. "A universal misfortune is scarcely a misfortune. It would be he whose unfortunately too-robust temperament would make him survive alone in an accident which had destroyed the whole human race except himself, who would have to lament! King of the whole Earth, possessor of all its treasures, he would perish of sadness and ennui: his whole life would not be worth the last moment of him who dies with those he loves."

Thus, in the last century, people still believed in the terrible power of these unhappy stars. In the present day, and especially since the famous comet of 1811, country people have imagined rather that they predicted excellent vintages. These ideas are as void of proof as the former. Although these bodies have greatly lost their prestige, they have not been entirely despoiled of it. Moreover, who could efface the impression produced by some of their aspects? Often they have been considered as signs of curses hovering over men and empires.

Nevertheless, nothing proves that comets are gifted with any influence whatever, I do not say on the morals of men, but on the physics of the world. Their lightness, the extreme diffusion of their substance, induces us to believe rather that they possess no kind of action on the planets. Let us imagine that they are harmless. Like atmospheric clouds, whose magnitude, form, and shade vary with the caprice of the winds and according to the fortuitous play of solar rays, the vaporous agglomerations which form comets take every possible form under the impulsion of cosmical forces more or less intense. At their approach to the fiery body, their substance distends itself, assumes a wonderful size, and develops itself over an expanse of many million leagues. They are of such lightness and suppleness that a ray of heat may, at its will, cause them to take any shape: you have an instance of this lightness in the comet recently observed in 1862; the form and position of the luminous appendages changed from day to day; and observers might have believed that even a portion of the substance of the nucleus flowed into space. On the other hand, their rarity is such that out of the tails of certain comets we should be able to cut a piece the size of Notre Dame, and inhale it as a homœopathic inspiration. Comets have been seen several million leagues long, whose mass was nevertheless so small that it would have been possible, without fatigue, to carry it on one's shoulder. Thus, the extreme variability of the cometary forms ought to proclaim these terrible bodies harmless.

And, indeed, these celestial bodies are not exceptional phenomena; they are subjected, like others, to the inexorable laws of nature. Two thousand years ago Seneca wrote, "A day will come when the course of these bodies will be known, and submitted to rules, like that of the planets." The prophecy of the philosopher is realized. It is now known that, like the planets, comets gravitate round the Sun, and depend equally on its central attraction. Only, instead of moving in orbits, circular, or nearly so, they describe oval curves—very long ellipses. This is the great distinction established between them and planets. Instead of being opaque, heavy, and important bodies like our planets, they are of great lightness, and extreme tenuity. One day, a comet carried away by its rapid march, traversed the system of Jupiter; the satellites and the planet were for some hours surrounded by the comet; and when the body had passed over them they had not undergone the slightest deviation in their path. When Maupertuis, wishing to explain the origin of Saturn's ring, thought he had conceived an ingenious idea in attributing this appendage to the tail of a comet which was wound round the planet, he did not dream of the extreme rarity of these impotent vapors.

The distinctive character of comets lies especially in the length of their course, and in the immense duration of their journeys round the Sun, through the celestial regions.

BOOK FOURTH.

I.

THE TERRESTRIAL GLOBE.

While reviewing the worlds belonging to solar rule, we passed over the space which separates Venus from Mars without noticing a body which occupies the mid-distance. This body, moreover, ought to interest us somewhat, for it relates to us more nearly than all the others.

The Earth, isolated in space like all the other planets that we have seen, is situated some 91 millions of miles from the Sun, and journeys along an orbit which it traverses in 365¼ days. Like some of its companions, it has a faithful attendant—a satellite revolving round it. This is its little system, and the Moon accompanies it humbly in all its voyages through space.

Like the other planets, also, it rotates on an axis with great rapidity, for at some parts of its surface bodies travel at the rate of 1000 miles an hour. It is spheroidal, and rather flattened at its poles, which proves its primitive state of fluidity. Of this state, a proof more easy to recognize still remains in its volcanoes, with their open craters, from which are ejected the interior substances of the Earth in the state of fusion, and at the high temperature in which they exist at the present time. Correctly speaking, the whole Earth is still a globe of liquid substances, melted by the intense heat which glows under our feet; for the solid stratum of this globe—the crust which surrounds it, and on which we live—is not, it has been estimated, a hundred miles in thickness. The Earth resembles a thin glass globe, a yard in diameter, filled with metals in a state of fusion. If there were not some apertures—that is to say, some volcanoes, to allow the vapors to escape, it might happen that the globe would burst. What is the real size of this globe? Imagine a gigantic die, each side of which would measure one mile in length; you would have then a volume of one cubic mile. To form a volume equal to that of the Earth, it would be necessary to heap up 260,613 millions of these cubic miles.

What is its weight? We have already glanced at it in speaking of the Sun's weight. To express it in tons, it requires a row of twenty-two figures.

The weight of the atmosphere which surrounds the Earth is not the millionth part of the weight of the whole Earth; yet each of us carries on our shoulders a pressure of about 8000 pounds. Let us add, in passing, that this pressure, although not to be despised, is not perceptible to us, because it is counterbalanced by an equal pressure exercised in the opposite direction by the fluids within our body.

The surface of the Earth is about 197,000,000 square miles. Of this surface the ocean occupies 145,000,000 square miles; only 52,000,000 therefore remain for *terra firma*. There is then only about a quarter of the Earth's surface which is habitable; the remainder lies hidden in the bosom of the waves.

By retreating into space we should be better able to judge of the Earth as a star. At the distance of the Moon, that is, about 240,000 miles, the Earth would appear to us as the Moon does, being not less luminous and much larger. At ten times this distance the Earth would still present to the naked eye a perceptible disk, and its light would be intermediate between that of the Moon and that of the stars. Again, at ten times farther, that is to say, at the distance of the orbit of Venus, the Earth would be seen under the form of a beautiful star of the first magnitude, without any appreciable disk, as a brilliant point, similar to Jupiter. But if we go farther still, the Earth, already promoted from the rank of a planet to that of a star of the first magnitude, will afterward fall from magnitude to magnitude to the last order of visibility, and would be finally lost in the depths of the invisible. It is scarcely necessary to add that the light with which it shines and with which it is radiant in space is no other than the light received by us from the Sun, and it would be seen under every possible phase, according as it would be observed fully lighted up, or from one side, or obliquely, or when turning round its opposite hemisphere to the Sun.

The Earth revolves round the Sun, with a

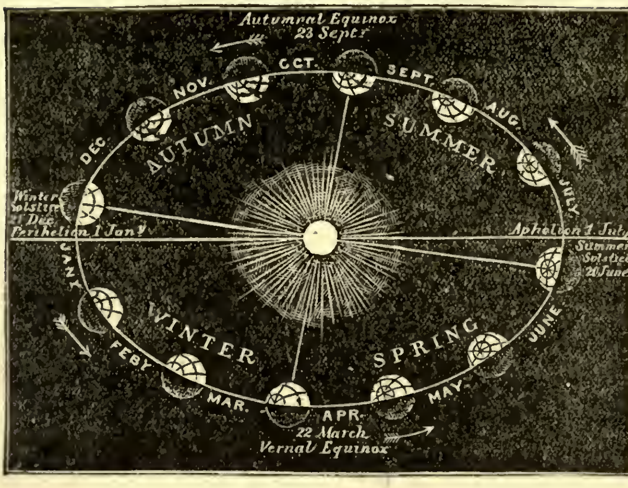


Fig. 30.—Orbit of the Earth.

movement of translation similar to that which we have noticed in the case of all the planets. It is this movement which constitutes its year. Its rotatory movement on its axis, which may be compared to that of a spinning top, constitutes its diurnal period, its day. It is to this second movement that we owe the illusion of the apparent movement of all the stars.

All that has been said on the diurnal movement of the stars round the Pole Star will be easily understood if we reflect that this star lies in the continuation of the axis of the Earth. The Earth turning, suppose, from left to right in our northern hemisphere, all the objects situated outside it, that is to say, the stars, appear to turn from right to left, in the direction contrary to the movement which carries us on. When you are in a railway carriage, if you forget the movement of the train, the objects you pass will appear to fly behind you, and if you did not know for certain that it was you who were moving, believing yourself stationary, you would have the conviction that it was the trees and hills which are travelling. A similar delusion presents itself when we find ourselves on the top of a high tower, and the clouds pass rapidly above us. It seems as if the tower advances and moves under our feet. One morning I was at the top of the steeple of Strasburg Cathedral; the sun had scarcely risen, and some clouds coming from the Rhine had entirely hidden the town and the whole lower space from me. These cloud-bands were driven by an east wind and passed below me. In spite of the complete certainty that I naturally had of the stability of the high cathedral, it was impossible to keep in my mind the feeling of reality, but the delusion carrying it away, I believed myself again in the train—the cathedral certainly moved toward Germany. I closed my eyes, but the movement continued its action in my mind, and it was not until ten minutes after, when the Sun had lighted up the scene and cleared away the vapors, that the roofs of Strasburg restored me to the reality. The apparent movement of revolution of the Sun round the Earth, which seems to be effected from east to west—the opposite of the real movement of the Earth, from west to east—constitutes our day and night. The moment at which the Sun attains the middle of its course, the culminating point, is that which divides the day into two equal parts. The opposite moment, when the Sun is diametrically under our feet, marks the middle of the night. From this it is evident that our noon is the midnight of the people who live in the countries situated on the opposite side of the Earth, and that, conversely, when they have noon we have midnight. The Sun then regulates time by passing over the heads of each of the nations which inhabit the globe. The civil day commences at midnight, and is composed of two periods: the morning, from midnight to noon; the afternoon, from noon to midnight. Astronomers do not follow this custom; they reckon their day from noon, and make of it one period, from 0 hour to 24 hours, which they count from noon to the following noon. Let us now see how the Earth is studied, and by what means its different parts are recognized.

As the Earth is a sphere, the two points at the opposite extremities of the ideal axis around which it rotates are called the poles. If we trace, perpendicularly to this axis, a large circle at an equal distance from the two poles, which would cut the sphere into two equal portions, this circle is the equator. Now the distance from the equator to the poles on each side of it is divided into ninety equal distances; these are degrees of latitude. Lastly, the great equatorial circle

itself, or the entire circumference of the globe, is divided into 360 equal parts by other great circles passing through the poles arranged on the sphere, like the slices of a melon; these are the meridians of longitude. There are, consequently, 180 in each half of the sphere, and ninety in each quarter. These names, longitude and latitude, date from a time when the terrestrial region, which had alone been measured, was supposed to be an oblong figure, the length of which extended in the direction of the equator, and the width in that of the meridians.

Degrees of latitude then are counted starting from the equator; either north or south, as far as the north pole or the south pole. The degrees of longitude cut them, and are counted from any point, being reckoned toward the east entirely round the globe. The line of the poles goes from north to south, or south to north, indifferently; the line of the equator goes from east to west, or from west to east. When we advance from the eastern to the western side we do not change

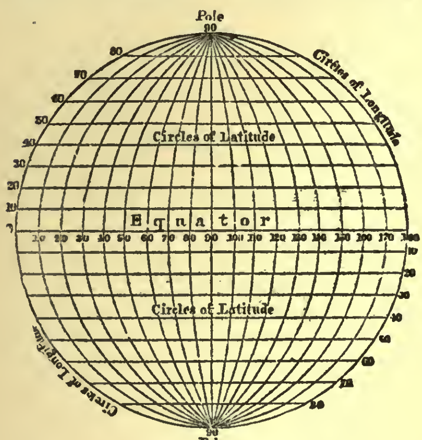


Fig. 31.—Divisions of the Globe.

our latitude, but our longitude. If, for instance, we go from Paris to Vienna, we shall have made fifteen degrees of longitude toward the east. As the Earth is 24,000 miles in circumference, we see that each of the 360 divisions *of its equator* (in other words, each of the degrees of longitude) is equal to 69½ miles; this value diminishes toward the poles. Moreover, as the sun employs twenty-four hours for the journey it seems to make, it appears to travel 15 degrees an hour, 180 in twelve hours, and 360 in twenty-four hours; each hour being equivalent to 15 degrees. Thus, at Vienna, noon is an hour earlier than at Paris. Going on toward the east, the traveller will gain an hour every fifteen degrees, and if he keeps his watch according to London time it will be on hour slow for every fifteen degrees. If he goes round the world travelling east, and if he sets his watch by the time of the countries through which he travels, it will advance on London time, in proportion as he continues his journey; when he arrives in London after having thus made the tour of the world easterly, he will have gained twenty-four hours, and will reckon a day more than we do: it will be Monday with him while with us it is Sunday.

It is on account of this difference in the time that if, on visiting the borders of the Rhine, you take the train at Kehl for Strasburg, as the Kehl station is regulated by the Baden time, and that of Strasburg by Paris time, you will arrive at Strasburg ten minutes before the time of your departure from Kehl.

For the same reason, when the Emperor of the French delivers his speech at the opening of the Chambers, this speech flying to London by telegraph, the conclusion may be read by us before it has left the lips of the Emperor, reckoning merely by time. The watch of another traveller, going west, will be too fast, unlike our preceding one; and if he sets it by the time of the countries through which he passes, on returning to London, after having gone round the world with him, it will only be Saturday, while with us it is Sunday. This singularity in the way of reckoning would be experienced every time a vessel arrived which had been round the world, if it had counted the days without conforming to the time of the countries through which it passed.

For the same reason, says Lalande ("Astronomie des Dames"), the inhabitants of the South Sea Islands, which are twelve hours distant from our meridian, must see that travellers who come from the Indies and those from America count the days of the week differently, the first being one day in advance of the others; for, supposing that it is Sunday at noon at London, those who are in India say that Sunday noon has already passed six or seven hours; and in America it will still be Saturday evening. This fact appeared very singular to our old travellers, who were accused at first of having made a mistake in their almanac, and of having lost the thread of their calculation. Dampier, on going westward to Mendanao, found that there they were a day in advance of him. Varenius said the same at Macao, a maritime town in China. The Portuguese always reckon a day in advance of the Spaniards at the Philippines, although not so distant; the former have Sunday, while the latter only count Saturday. The reason of this is, that the Portuguese who settled at Macao went there by the Cape of Good Hope, travelling from the west—that is to say, starting from America and crossing the South Sea.

It will be seen from this sketch that the Earth is a planet, and is regulated by planetary movements; that there is nothing absolute in any of these data of time and space; that all is relative to the condition of each planet; and that on each of the planets these elements differ according to their magnitude, as do the movements which give rise

to them. But, it may be asked, on what grounds are these theoretical rules established, and what proves to us that, on the other hand, the Earth is not the absolute fixed world, established as the base of the heavens, and that all these movements are not real as they appear? How can it be proved that this is delusion of our senses; and, since it has been discovered only through observation, how has it been known that these are only simple appearances?

If you will listen to me for a few moments you will be as convinced on this subject as I am.

II.

PROOFS THAT THE EARTH IS ROUND—THAT IT TURNS ON AN AXIS, AND REVOLVES ROUND THE SUN.

I HAVE known people who were never so eager as when addressing a thousand astronomical questions to me, and who had no sooner received my answers than they ridiculed all with the greatest ingenuity. Without noticing their really primitive rudeness, it was astonishing to see them, at the same time, so curious and yet so difficult to please. In their eyes scientific men were dreamers, who fancied they understood, but who, in reality, were as unable as the rest of the world to discover the secrets of nature.

I have known others, a little more intelligent than the former, but who, considering the different phases of the history of the science, its successes and its reverses, thought that we turn in a vicious circle, that we do not possess the true knowledge of things, and that our systems, however solidly based they may appear, must never be received but as hypotheses.

The cosmographical question which touches us most nearly, that of the isolation and movement of the Earth in space, especially dissipates the doubts of which I speak. For those who have heard these doubts stated, and who have not always undeniable proofs ready to hand, I shall give here the fundamental points on which this element of the new system of the world rests. We state, first, that the Earth is round; that it has the form of a sphere rather flattened at the poles. The first fact which bears testimony to this is the convexity of the immense expanse of water which covers the greater part of the globe. The mere sight of a ship at sea suffices to prove this curvature. On reaching the blue line which seems to form the separation of the sky and the water, the receding ship appears for a moment to rest on the horizon. A little later it disappears, not the upper, but the lower part. The sea rises at first between the hull and the observer; afterward it hides the lower sails; the tops of the masts are the last to disappear. A similar phenomenon is visible to an observer placed on the ship; the lower coasts vanish first; the buildings, high towers, and lighthouses being the objects which remain longest visible. This double fact proves, in an evident manner, the convexity of the sea. If it were a plane surface, the distance alone would hide a vessel, and in this case all would disappear together, the upper as soon as the lower sails.

It follows, moreover, from this same kind of observation, that the curvature of the ocean is the same in every direction; now this property belongs only to the sphere.

The convexity of the sea extends itself to the solid land. In spite of the inequalities of the ground, the surface of the continents does not differ essentially from the seas; for it is known that the highest chains of mountains are far from producing, on the general surface of the Earth, protuberances comparable to the corrugations of the skin of an orange. Now, the rivers which divide the solid Earth in every direction, to be again united in the ocean, are scarcely higher than its level, and may be considered as the continued surface of the sea throughout the whole extent of the continents. The barometric measures of the heights of mountains have confirmed this fact. The land of the continents deviates little from this level, and presents, as a whole, a curvature entirely like that of the seas. Moreover, on the land as on the sea, the highest objects are always the first and last which the traveller sees.

Voyagers of circumnavigation have, on the other hand, given a palpable proof of the sphericity of the Earth. The first of the navigators who undertook the daring enterprise of going round the world was the Portuguese, Magellan, who left Spain in 1519, going always to the west. Without having changed its direction, one of his vessels (that of Lieutenant Cano) reached Europe three years afterward, as if it had come from the east. The numerous voyages of circumnavigation accomplished since that time have superabundantly confirmed this truth—the Earth is round in every direction.

Another proof of the convexity of the Earth is furnished by the change of aspect undergone by the heavens during voyages. If we steer toward the pole or approach the equator, fresh stars are continually seen; in the same way, those of the latitudes which we leave behind are lost to sight. This appearance can only be caused by the roundness of the Earth; if the Earth were a plane, all the stars would be visible at the same time.

The shadow thrown by the Earth on the Moon, during eclipses, is always circular, whatever side the terrestrial disk at the time presents to the lunar disk. This conical shadow, invariably observed, is a fresh proof in favor of the sphericity of the Earth.

Such are the common facts which prove, in a positive way, the truth we have put forward. If we desired to enter into questions of geodesy or mechanics, I could present more rigorous considerations still; but the preceding proofs are sufficient for us here.

Let us now see what basis of truth they have who assert that the Earth is isolated and in motion through space. The difficulty which certain minds have in believing that the Earth can be suspended like a bal-

toon in space, and completely isolated from every kind of support, proceeds from a false notion of gravity. The history of ancient astronomy shows us the profound perplexity of the first observers who began to conceive the reality of this isolation, but could not understand what hindered this heavy globe, on which we live, from falling. The early Chaldeans supposed the Earth hollow, and similar to a boat; it could then float on the abyss of the ether. Some ancients fancied that it rested on pivots placed at the two poles. Others supposed that it stretched indefinitely below our feet. All these systems were conceived under the impression of a false idea of gravity. To rid ourselves of this old delusion, it is necessary to know that gravity is only an effect produced by the attraction of a centre. A body never falls but when the attraction of another more important body solicits it. The expressions "from above" and "from below" can only be applied to a determined material system, in which the attractive centre may be considered as the bottom; beyond this they signify nothing. When, then, we suppose our globe isolated in space, we do nothing which can give rise to the objection before mentioned—namely, that the Earth will fall.

The Earth may be isolated in space. But not only may it, but it is so in reality. If it were supported by a neighboring body at some point of its surface, this support, which would necessarily be of very great dimensions, would certainly be perceived when it was approached. It would be seen projecting from the Earth and losing itself in space. There is no necessity to state that travellers who have gone round the world in every direction have never perceived anything like this; the terrestrial surface is entirely detached from everything which exists around it. We now come to the third point of this chapter, to the positive proofs of the Earth's motion.

Let us notice, first, that the appearances of exterior objects will be identically the same to us whether the Earth being in repose these objects are in motion, or these objects being in repose the Earth itself is in motion. If the Earth carries in its movement everything which belongs to it—seas, atmosphere, clouds, etc.—we should only be conscious of this movement, in which we participate, by the changing aspect of the immovable sky. Now as, in both cases, the appearances are the same, we are going to show that the hypothesis of the Earth's movement explains everything, while without it we fall into an inacceptable complication of systems.

If the Earth turns on its axis in twenty-four hours, we see directly that its mean radius being some 8000 miles, and its circumference 24,000, a point situated on the equator would travel 1000 miles an hour. This velocity, which seems considerable, has been thought to be an objection against the movement of the Earth. But we shall see with what tremendous velocity it would be necessary to animate the heavenly spheres to cause them each to traverse the circumference of the heavens in the same lapse of twenty-four hours.

In the first place, the Sun being distant from the Earth 23,000 times the terrestrial radius, on the hypothesis of the immobility of the Earth, the Sun would describe a circumference 23,000 times greater than the equator, that is, it would travel 23,000 times 1000 miles an hour!

Jupiter is about five times farther away; its velocity would be more rapid still; Neptune, thirty times; it would travel still faster. Such would be the different velocities with which the planets would be animated if they revolved round our globe in twenty-four hours, at they appear to do. It shows that the objection against the movement of the Earth on the ground of rapid motion is untenable. What would this motion be if we should consider the fixed stars? Our neighbor, the star α of the Centaur, must travel more than a million times faster than 1000 miles an hour, and so on with all the stars, until with the more distant ones we should fail to find a number to express the velocity of their motion in revolving around this invisible point which we call the Earth.

Let us add to this that these bodies are, one, 1400 times larger than the earth, another, 1,400,000 times, and others more bulky still; that they are not united one to the other by any solid tie which connects them with the movement of the heavenly vault; and that they are all situated at the most diverse distances; and this fearful complication of the system of the heavens will itself bear witness of its non-existence—we might say of its mechanical impossibility.

But not only is it impossible for the diurnal movement of the celestial sphere to be understood except by the admission of the movement of the Earth on its axis, but the movements of the planets in the zodiac, their stations and retrogradations, demand it as imperatively. To explain the planetary appearances, supposing the Earth immovable, the ancients imagined as many as seventy circles placed one within the other, solid circles or crystal heavens, which nothing could surpass in complication, and which if they could exist for an instant would have soon been dashed to pieces by wandering comets or aerolites which we meet in space.

Again, on the other hand, analogy singularly confirms the hypothesis of the movement of the Earth, and changes into certainty its great likelihood. The telescope shows in the planets, globes analogous to our own, which have a rotatory movement on their axes, a rotatory movement of twenty-four hours' duration in the case of the nearest planets, and of a less duration still in the case of the more distant ones. Thus, simplicity and analogy are in favor of the Earth's movement. Let us now add, that this movement is rigorously required and determined by all the laws of celestial mechanics. The great difficulty which has been

advanced against the movement of the Earth, and which was in favor for some time, was this: if the Earth turns under our feet, if we raise ourselves up into space, and find the means of supporting ourselves for a few seconds or more, we ought to fall after this length of time on a spot more to the west than the starting-point. For instance, at the equator, he who could find means to support himself immovable in the atmosphere for half a minute, must fall some miles to the west of the place whence he started. This would be an excellent way of travelling, and Cyrano de Bergerac claimed to have used it when, having raised himself in the atmosphere by a balloon of his own, he fell, a few hours after his departure, in Canada instead of coming down again into France. Some sentimentalists, Buchanan among the rest, have given to the objection a more tender form, saying that if the Earth revolved, the turtle-dove would never dare to rise from her nest, for soon she would inevitably lose sight of her young ones.

The reader has already replied to this objection by considering that all that belongs to the Earth participates, as we have stated, in its rotatory movement, and that to the last limits of the atmosphere our globe draws all in its course.

Direct observation of different phenomena has confirmed the theory of the movement of the Earth, and has confirmed it by undeniable material proofs.

If the globe turns, it develops a certain centrifugal force; this force will be *nil* at the poles, will have its maximum at the equator, and will be greater in proportion as the object to which it is applied is at a greater distance from the axis of rotation. This is, on a large scale, similar to that which exists on a smaller one in the case of a string, or wheel in rapid movement. Now, let us suppose that we fix a plumb-line to the top of a tower, and allow the weight which stretches it to descend to the ground; the direction of this plumb-line toward the centre of the Earth, that is to say, the perpendicular to the water level, will be slightly modified by the effect of the centrifugal force, resulting from the rotation of the globe, measured at the foot of the tower. If we fix also at the top of the tower, a little to the east of the first, a second very short plumb-line, so that its weight is situated a little below the point of joining, this second line will not have quite the direction of the first, for the centrifugal force due to the movement of the Earth being greater at the top of the tower than at the foot, will cause the line to deviate a little to the east. This minute observation has been made and repeated with the greatest care; it is, in its way, a proof of the rotation of the Earth.

The oscillations of the seconds pendulum support the foregoing fact. Not only are they slower at the equator than at the poles, because the equatorial radius is greater than the polar radius, but the difference is too great to be attributed to this cause alone. At the equator the centrifugal force partly counterbalances the effect of the weight. A curious remark to be made here is, that at the equator this force is $\frac{1}{289}$ of the weight. Now, as the force increases in proportion to the square of the velocity of rotation, and as 289 is the square of 17, if the Earth turned 17 times quicker, bodies at the equator would no longer weigh anything; a stone thrown into space would not fall.

Here is another fact no less positive than the preceding, and more easy to appreciate, as another proof in favor of the movement of the Earth. If the Earth were immovable, and the starry sphere revolved round it in twenty-four hours, the stars would never pass the meridian, would never rise or set, at the time predicted from their longitudes in the heavens. The luminous rays which they send to us, taking unequal intervals to reach us according to their relative distances, would cause an extreme confusion in the hours of their apparent passages. A star, for instance, which, in reality, passes now at the meridian, but is situated at such a distance that its light takes six hours to reach us, will only appear to pass it six hours later, that is to say, at the time of its setting. Another will be twelve hours late; another months or years, and so on. This is another material proof that it is not the heavenly spheres which move, but the Earth itself. The real annual movements of the stars in the heavens, of which we have spoken when stating the method used to determine the distances of the stars, furnish an equally positive proof of the movement of the Earth round the Sun. It is the same with the phenomenon of the aberration of light. The physics of the globe also furnish their contingent of proofs to the theory of the movement of the Earth; and it may be said that all branches of the sciences, nearly or distantly connected with cosmography, are united in the unanimous confirmation of this theory. The very form of the terrestrial spheroid shows that this planet was a fluid mass animated with a certain velocity of rotation, a conclusion to which geologists have arrived in their researches. Other facts, as the currents of the atmosphere and the ocean, the polar currents and the trade-winds, equally find their cause in the rotation of the globe; but these facts have less value than the preceding ones, seeing that they might agree with the hypothesis of the movement of the Sun.

We shall conclude by recalling M. Foucault's brilliant experiment at the Pantheon, in Paris. Unless we deny the evidence, this experiment proves indubitably the movement of the Earth. It consists in fixing a steel wire by its upper end into a metallic plate, solidly fitted into a ceiling. The wire is then stretched at its lower end by a rather heavy copper ball. A pointer is attached below the ball, and fine sand spread on the ground to receive the trace of this point. We have a long pendulum; and when the pendulum is in motion it happens that the

point does not always trace the same line in the sand. Successive traces which cross at the centre follow each other, and show a deviation in the plane of the oscillations from east to west. In reality, the plane of the oscillations remains fixed; the Earth turns underneath from west to east. This last experiment has placed the seal on the positive proofs of the movement of the Earth.

Thus, like all the heavenly bodies, the Earth revolves. Absolute repose does not exist in the universe; all is in motion; and it is on this universal law of movement that the stability of the world rests.

But a question presents itself here: the Earth turns; we grant it! But is it possible for it to stop? Or what would happen if, by any chance, it ceased suddenly or by degrees, to revolve in its rapid motion? Let us see: the subject is worth the inquiry, as it is very curious. In trying to reply to this strange question, I wish to give it more importance than it really possesses. That our globe will one day cease to revolve is what we may fearlessly declare impossible; and that with all the authority which belongs to the principles of celestial mechanics. On the part of our world, we have nothing to expect or to fear from this chimera. I say, to fear! For here are the inevitable consequences which would follow from the simple arresting of the Earth in its course.

Let us first call to mind that the motion of a body situated on the surface of the Earth is composed of two portions—the movement of diurnal rotation of the globe on its axis, and its movement of translation round the Sun. In virtue of the first, the bodies placed on the terrestrial equator travel 1000 miles an hour. This velocity diminishes from the equator, where it is a maximum, to the poles, where it is *nil*, as bodies have naturally so much longer a path to travel as their latitude is less. In consequence of the second movement of the Earth—its revolution in space round the Sun—each particle of its mass travels 68,000 miles an hour.

An idea may be formed of this velocity if we reflect that an express train at full speed does not go more than sixty miles an hour, and that a 24-pounder ball has only, on its leaving the cannon, a velocity of some 300 yards a second.

As every part belonging to a material system in movement is animated with the same motion, if by an abrupt stoppage this system is suddenly brought to repose, the portions which can be displaced at its surface will continue, in virtue of the acquired velocity, to move in their original direction. It is on account of this principle that when your horse suddenly falls under the pole of your rapid chariot, you find yourself unfortunately thrown over the head of your Pegasus. It is also in virtue of the same principle that you must take certain precautions in descending from an omnibus in motion, since your feet being suddenly placed on the immovable ground while your body is still animated with the acquired velocity, you are inclined to tumble forward.

The Earth is, as we have seen, a more rapid conveyance than omnibuses, carriages, or trains. If it were to stop suddenly, all precautions would, without doubt, be unavailing to avoid instantaneous death. All objects which are not implanted and fixed in the ground, all which only adhere to the surface by the law of gravity, would be immediately, and all together, projected into space with a tremendous velocity—with the velocity, in fact, of the Earth in its orbit. Peaceful pedestrians, laborers, and quiet people, domestic and wild animals, the birds of the air, our carriages and machinery—all would be sent forth at a single bound in the direction of the movement of the Earth. As to the ocean, which covers two thirds of the globe, its liquid mass, rushing over the shores would submerge in the twinkling of an eye the islands and continents in its impetuous course, crowning the edifice of death. Soon it would reach above the highest mountains, and would cause our globe to undergo a transformation of surface, such as the ancient revolutions which have disturbed it have never equalled. Theorists who occupy themselves in finding a natural cause for the biblical deluge have not omitted to bring forward this powerful one, and to suggest that the shock of a comet would easily effect this arrest and its sad consequences. We now know that a comet could pass over the Earth without our perceiving it.

Another very curious fact which would follow the annihilation of the velocity of the Earth is this: the centripetal force which attracts the planets toward the Sun being no longer counterbalanced by the centrifugal force, the Earth would fall in a straight line into the Sun. If there were any other beings on the globe besides the fishes to see it, the Sun would be seen to increase visibly, and to swell out gigantically. The Earth would reach it sixty-four days after the shock, and would disappear in its surface as an aerolite does on the surface of the Earth.

Of course our globe is not an exception to the general rule; the same end would happen to the other planets if they found themselves in the same case. Thus, if the motion of Mercury, Venus, Jupiter, or Saturn were stopped, these planets would fall into the Sun—the first in fifteen, the second in forty, the third in seven hundred and sixty-seven, the last in nineteen hundred days.

But here is another consequence, still more curious, which would immediately follow from the sudden stopping of the Earth in its course.

It is acknowledged that motion can no more be annihilated than any atom of matter; it may be communicated, divided, or hidden in a certain quantity of other forces, but not annihilated. It may—and this is the important point here—it may be transformed into heat; and it is actually so transformed every time it appears to be lost as motive

power. Thus you strike a nail, firmly driven in and immovable, several times : the movement of the hammer not being communicated to the nail, is transformed into heat- you can easily perceive it by the touch. It is needless to multiply examples : every one has proved by experiment this mechanical transformation of heat.

Now, if by any cause the motion which animates our globe should be instantaneously suspended, this motion would unerdgo this transformation of which we have spoken. The Earth would be all at once heated ; and do we wish to know to what degree ? The quantity of heat engendered by the arrest of the terrestrial globe due to a colossal shock would not only suffice to melt the whole Earth, but also to convert the greater part of it to a state of vapor.

This consequence crowns and absorbs all the preceding ones. The Earth would no longer be a planet ; its volume and density would be changed entirely, and what we have just pointed out as to the inordinate movement of the bodies on its surface, the overflowing of the seas, and its fall into the Sun, would no longer be applicable ; all these consequences suggested by mechanics would be modified according to the force which impeded the movement of the Earth. If this stoppage were only a progressive slackening, the accomplishment of which would require a length of time instead of being instantaneous, the Earth would still become hot enough to cause all living beings on its surface to perish suddenly.

Let us conclude these reflections as we began them, by stating that the question is more curious than important ; and that it is very certain we may rest in peace without allowing the slightest trace of imaginary fears, which might at first sight spring up in our minds, to trouble us.

III.

THE MOON.

THE orb of reverie and mystery, the torch destined for the lighting-up of our terrestrial nights, has always been privileged to attract our sight and occupy our thoughts. Reigning over the empire of silence and peace, it seems more mysterious and solitary than any other ; its white and frosted light also adds to the first impressions ; and it remains in the mind as representing night itself. In olden times the ancients named the sovereign of the silent nights Diana with the silver crescent, or Phœbus with the fair hair.

Attached by indissoluble ties by means of attraction to the Earth from which it is descended, the Moon gravitates round us like a faithful satellite. At the time of its greatest brightness, when it is at its phase of full Moon on rising, it introduces the time of the appearance of the stars, and perceptily following their course from east to west, it appears their heavenly guide.

Nevertheless, as it makes the circuit of our globe from west to east in about twenty-seven days, it is soon remarked that each day it falls behind the stars which it seems to conduct, and that it possesses a movement independent to that of the celestial sphere. Indeed, it is the nearest heavenly body to us, and it belongs to us as a satellite.

Of all bodies, this is the one we understood the first and best. Since the invention of the first telescopes—scarcely 250 years ago—these primitive instruments whose power was far from attaining the stellar regions, and could only be effectually applied to this nearest body, astronomers, astrologers, alchemists, and all those who were occupied with science, found themselves urged by a desire to penetrate into the mysteries of this celestial land. The first observations of Galileo did not make less noise than the discovery of America ; many saw in them another discovery of a new world much more interesting than America, as it was beyond the Earth. It is one of the most curious episodes in history, that of the prodigious excitement which was caused by the unveiling of the world of the Moon. "*Ce n'est que le premier pas qui coute,*" says the old proverb ; at the time of which I speak, only the first step in optics had been taken ; scarcely was it made, but a second was claimed with avidity, then the third ; and as science did not advance as quickly as was desired, as many years passed without the kingdoms of the Moon and the cities of its inhabitants being discovered, exalted imagination without waiting longer took flight to the new celestial world. Very curious voyages to the Moon then appeared, astonishing excursions, unpardonable fancies ; and serious studies were soon eclipsed by the visions of impatient minds. Notwithstanding all this, astronomical discovery rapidly advanced. Encouraged by the first revelations of the telescope, astronomers undertook the complete study of the lunar surface. The aspect of the Moon to the naked eye, that rude face that was seen with little good-will on its pale disk, was transformed in the field of the telescope, and at first very bright portions and very dark portions were alone distinguished. Examining it more attentively, and increasing the magnifying power of the instrument, it was discovered that the aspect of the details changed according as the Sun was on one side or the other of the Moon ; that on the days when the Sun was at the left of the bright portion dark lines were seen to the right, while in the opposite case, the dark shadow appeared to the left. It was then easy to prove that the bright portions were mountains, that the dark portions which were close to them were valleys, or low countries ; and lastly, that the large plains were lands which reflected the solar light less perfectly.

It was already known that the phases of the Moon were produced by the illumination of the Sun, because when we see entirely the lighted-up portion of the Moon, at the time of full Moon, it is when we are between the Sun and the Moon, and that the side that the

Sun entirely lights up is turned toward us; that at the time of the new Moon, the Sun is behind the Moon, and lights up the side that we do not see, and that at the two quarters we make a right angle with the Moon and Sun, and can see only one half of the portion which the Sun lights up. Observations made with the telescope confirm this explanation by showing that the path of the shadows on the surface is opposed to the direction of the Sun. Later, indeed only a few years ago, this was again confirmed by spectrum analysis, of which I have before spoken, for, on analyzing the rays sent us by the Moon, astronomers found indication of identically the same elements as in the light emitted directly by the Sun.

We have then before our eyes a globe, opaque like the Earth, lighted like it by the Sun, and its surface marked with mountains and valleys. This was more than was necessary to incite curiosity. Astronomers then employed themselves specially with our neighbor, and planned a geographical, or more properly, selenographical, map of it, since, as the reader may know, Γή means the Earth, while Σέληνη means the Moon.

As astrological ideas on the physical and metaphysical, moral or immoral influences of the Moon were still in full vigor, and man could not, but with the greatest difficulty, free himself from error, even when he wished, which is unfortunately but seldom the case, astrologers continued to interpret the language of the Moon according to the rules of the horoscope, and astronomers gave a description which agreed with the reigning opinions. To the large spots they gave the name of seas, to the small ones lakes or marshes; then they christened the seas, lakes, marshes, mountains, valleys, gulfs, peninsulas, etc., with names connected with the remembrance of virtues more or less legitimately attributed to the orb of night. Thus there were, and are still at the present time on the Moon, the Sea of Plenty, Lake of Dreams, Sea of Serenity, Marsh of Fogs, Ocean of Tempests, Lake of Death, Sea of Humors, Marshes of Putrefaction, Peninsula of Reveries, Sea of Tranquillity, etc., etc., and other names which are not all, as you see by the preceding, in exquisite taste or of graceful sentiment. When it was necessary to name the mountains, the first idea was to name them after the astronomers whose works had been most useful in the advancement of our knowledge of the Moon, and had most brilliantly illustrated this ornament of space. But a consideration of prudence deterred Hevelius, the author of the "Selenographia," and one which it will not take long to guess—he feared to excite sentiments of jealousy. An astronomer who did not possess a plot of land here was honored to receive a small heritage in the lunar world; but another, a rich proprietor, was (as it always happens with people of this kind) very angry not to increase his wealth by some part of the Moon. Then the names of the mountains of the Earth were given. There were the Alps, Apennines, Carpathians, etc.; but the vocabulary of our mountains was not sufficient, so they returned to the learned men, but to those who were dead. Aristotle, Plato, Hipparchus, Ptolemy, Copernicus, each had their property in the Moon. Certain travellers, like the author of the "Voyage au monde de Descartes," have found, on visiting these different lunar countries, that the great men whose names they had arbitrarily received, took possession of them in the course of the sixteenth century, and there fixed their residence. These immortal souls, it seems, continued their works and systems inaugurated on Earth. Thus it is that on Mount Aristotle a real Greek city has risen, peopled with Peripatetic philosophers, and guarded by sentinels armed with propositions, antitheses, and sophisms, the master himself living in the centre of the town in a magnificent palace. Thus also in Plato's circle live souls continually occupied in the study of the prototype of ideas. Two years ago a fresh division of lunar property was made, some astronomers being generously enriched.

Without taking up our time at present with the inhabitants of the Moon, the souls of those whose illustrious names have served to point out the kingdoms of the Earth, we can continue our narrative by saying that the satisfactory knowledge which people rapidly acquired of our satellite was due to its great proximity to the Earth, and to the facility with which we see all that passes on its surface. It is indeed so near to us, that after the celestial distances to which we must have familiarized ourselves in the preceding chapters, the distance which separates it from us is but trifling. Even to those whose minds have not visited the ultra-terrestrial regions, the path from here to the Moon is not very long. Navigators of long service who have made four or five voyages round the globe have travelled an equal distance, for in going round the world the irregularities of the route double the geometric circumference. A body allowed to fall from the lunar orbit would arrive here in 3 days 1 hour 45 minutes and 13 seconds. To go from here to the Moon it would take rather more time; but if we availed ourselves of steam, one could arrive there in less than a year. At its minimum distance it is only twenty-eight times and a-half the diameter of the Earth, or about 225,719 miles. This is really an insignificant distance.

It is doubtless this proximity which has caused the great reputation of the lunar orb among us. No celestial body, except the Sun, has ever had a similar influence. The whole world was accessible to the lunar influences—men, animals, plants, minerals. I have before stated that the astrological opinions with regard to this body were most singular. I must quote some to you: they are really too curious to be passed over in silence. Let us choose one or two good astrologers, learned on the Moon, and let us

question them. First, regarding the general action of the satellite on the Earth.

Cornelius Agrippa, a famous geomancer, thus expresses himself: "The Moon is called Phœbe, Diana, Lucinus, Proserpine, Hecate, who govern the months, half-formed; who illuminates the nights, wandering, in silence, with two horns; queen of divinities, queen of heaven, queen of *manes*, who rules over all the elements, to whom respond the stars, to whom return the seasons, and whom the elements obey: at whose direction the thunders sound, the seeds germinate, the germs increase; the primordial mother of fruits, heart of Phœbus, shining and brilliant, carrying light from one planet to another, illuminating by her light all the divinities, stopping various intercourses with the stars, distributing the light rendered uncertain on account of meetings with the Sun; queen of beauty, mistress of shores and winds, giver of riches, nurse of men, governor of all states good and unhappy; protecting men by sea and land, moderating the reverses of fortune; dispensing with destiny, nourishing all which comes out of the Earth, arresting the insults of phantoms, holding the cloisters of the Earth closed, the heights of Heaven luminous, the currents of the sea salutary, and ruling at will the deplorable silence of the lower regions, governing the world, treading Tartarus under foot; of whom the majesty causes the birds which fly in the sky, savage beasts in the mountains, the serpents hidden under the Earth, and the fish in the sea, to tremble."

According to La Martinière, "This lunar planet is damp of itself; but, by the radiation of the Sun, is of various temperaments, as follows: in its first quadrant it is warm and damp, at which time it is good to let the blood of sanguine persons; in its second it is warm and dry, at which time it is good to bleed the choleric; in its third quadrant it is cold and moist, and phlegmatic people may be bled; and in its fourth it is cold and dry, at which time it is well to bleed the melancholic. It is a thing quite necessary to those who meddle with medicine to understand the movement of this planet, in order to discern the causes of sickness. And as the Moon is often in conjunction with Saturn, many attribute it to apoplexy, paralysis, epilepsy, jaundice, hydropsy, lethargy, catapory, catalepsy, colds, convulsions, trembling of the limbs, etc., etc. I have noticed that this planet has such enormous power over living creatures that children born at the first quarter of the declining Moon are more subject to illness, so that children born when there is no Moon, if they live, are weak, delicate, and sickly, or are of little mind, or idiots. Those who are born under the house of the Moon, which is Cancer, are of a phlegmatic disposition."

According to Eteilla, the Moon "governs comedians, butchers, tallow and wax chandlers, ropemakers, lemonade-venders, publicans, playwrights of all kinds, masters of great works, menageries of animals; and, on the other hand, professional gamblers, spies, sharpers, cheats, bankrupts, false money-coiners, and madhouses; that is to say, the Moon rules over all those whose business it is to work during the night until sun-rising, or to sell provisions for the night: and it also rules over all which people would be ashamed to commit in full day, in sight of those who have manners. Thus each reader, on reading, may easily find out of what denomination he is, etc. It is well to mention, that the Moon also governs all small merchants, who merely distribute imports, all usurers, courtiers, horse-dealers, place-hunters, men without employment, feeding on clients, and placing by their craft honest people in peril of losing. . . . It is not without a cause, one would say, with regard to these accusations that the Moon is so near us; if it were as far off as Saturn, it would not be able to answer to all of them."

But intelligent and animated beings alone were not subjected to these pernicious influences; all terrestrial nature, including vegetables, and minerals, was under its rule.

Cucumbers increase at full Moon, as well as radishes, turnips, leeks, lilies, horse-radish, saffron, etc.; but onions, on the contrary, are much larger and better nourished during the decline and old age of the Moon than at its increase; and during its youth and fulness, which is the reason the Egyptians abstained from onions, on account of their antipathy to the Moon. Herbs gathered while the Moon increases are of great efficacy. "If vines are trimmed at night when the Moon is in the sign of the Lion, Sagittarius, the Scorpion, or the Bull, it will save them from field-rats, moles, snails, flies, and other animals. Pliny asserts that *aulx* sown or transplanted, the Moon being below the horizon, and gathered the day that it is new, will have no bad odor, and will not cause the breath of those who partake of them to be either offensive or disagreeable."

IV.

THE MOON (CONTINUED.)

On approaching the Moon, nothing is seen of the physical causes which make the Earth a vast laboratory wherein a thousand elements contend or unite with each other. There are none of those tumultuous tempests which sometimes sweep over our inundated plains; none of those hurricanes which descend in waterspouts to be swallowed up in the depth of the sea; no wind blows, no cloud rises to the heavens. There white trains of cloud vapors are not seen, nor those leaden masses with heavy cohorts: the rain never falls; and neither snow, nor hail, nor any of the meteorological phenomena are manifested there.

But, on the other hand, the magnificent tints which color our sky at sunrise and twilight, the radiation of the heated atmosphere, are never seen there; if winds and tempests never blow, neither is there the balmy breeze

which descends upon our coasts. In this kingdom of sovereign immobility the lightest zephyr never comes to caress the hill-tops; the sky remains eternally asleep in a calm incomparably more complete than that of our hottest days when not a leaf moves in the air. This is because on the surface of this strange world there is no atmosphere. From this privation results a state of things difficult to realize. In the first place, the absence of air implies also the absence of water and every liquid, for water and liquids can only exist under atmospheric pressure: if this pressure is taken away they evaporate, and their beds are dried up. Thus, for instance, if you place a vessel filled with water under the receiver of an air-pump, and then, by pumping out the air, which is in the receiver, you make a vacuum, you will soon see the water boil, even when the place where the experiment takes place is frozen with the most intense cold. The boiling disengages vapors, and, finally, the water is evaporated. Now let us suppose that, at a certain period of its past existence, the Moon had, like the Earth, seas and rivers, and that by the aid of any apparatus, its seas and rivers were made to boil and to fall into vapor again; by continuing this operation long enough the Moon would be made completely dry: this is precisely what has happened. Since the distant period of its formation in a fluid state, it has lost all its liquids and vapors, and now a linnet would die of thirst in the midst of the seas of the Moon. These seas do not contain a drop of water. These, it will be said, are singular seas. And, indeed, no one will hold that their title is logical. But we have seen that they were named at a time when people did not know the lunar surface sufficiently well to guess that it existed without air and water. From the absence of air follows another very curious fact—the absence of sky. On the surface of the Moon, when the looks are directed toward the sky, there is none to be seen. An immensity without depth is traversed by the sight without resting on any kind of form, and in the day as in the night are seen the stars, planets, comets, and all the bodies of our universe. The Sun passes among them without extinguishing them, as it does to us. Not only does the Moon not possess this perpetual diversity which the movements of the air produce on our world, but it has not the azure vault which covers the Earth with such a magnificent dome; space is a black and a perpetually black abyss.

While on high there reigns darkness, below there is silence. Not the least sound is ever heard; the sigh of the wind in the woods, the rustling of foliage, the song of the morning lark, or the sweet warbling of the nightingale never awakens the eternally dumb echoes of this world. No voice, no speech has ever disturbed the intense solitude with which it is overspread. Unchangeable silence reigns there in sovereignty. Tall perpendicular mountains divide its surface. Here and there are seen worn-out craters rising toward the sky, white rocks heaped up like the ruins of some long-passed revolution, crevices crossing the surface as in lands dried by the burning rays of long summer days. That which renders the spectacle more strange is that the absence of vapors causes the absence of perspective as well as the absence of all tints, and we see only white or black according as the object is in the Sun's light or in shadow, the objects succeeding each other as far as the horizon without losing brightness or contour. In the vicinity of the Southern pole, that is to say, at the lower part of the Moon as seen with the naked eye, are the highest mountains of the satellite: Doerfel, whose top attains a height of 26,691 feet above the level of the neighboring plain; Casatus and Curtius, 7,600 and 7,318 yards; Newton, 23,853 feet in depth; this word depth may justly be questioned when it refers to the elevation of a mountain; but the Moon is such a singular world that its mountains may be measured as well by depth as height. This paradox, rather difficult to understand, arises from the fact that the mountains of the Moon are not like those of the Earth, but are hollow. When we arrive at the top there is a ring, the interior of which often descends below the surrounding plain: so that if one did not wish to make the round of the slopes which sometimes measures 310 miles (Ptolemy), and even 403 miles in circumference (like the circle of Clavius), it would be necessary to descend three or four miles to cross the bottom of the crater, and afterward to ascend on the opposite side of the ring, to return at last into the plain.

Among the annular mountains may be mentioned that of Aristillus, situated in the Sea of Rains, not far from the Caucasus, between the Marshes of Fogs and Putrefaction. It is a curious fact that the surface of the lunar hemisphere was known before that of our own Earth, and the heights of all its mountains were measured before the same thing was done for our own. The volcano of Aristillus in particular was one of the first and best known. Lecouturier, the author of a very good map of the Moon, gave a long description of it, and this description may be applied to most of the lunar mountains. It is composed of a crater about twenty-four miles across, from the centre of which rise two cones, the highest of which attains nearly 984 yards; the whole is surrounded by a circular rampart, the highest part being 3,608 yards high. When the bottom of the crater is examined with a powerful telescope and under favorable circumstances, numerous rough portions are noticed which seem to indicate hardened lava and blocks of rock heaped together. From this mountain, taken as a centre, start five or six lines and rocky ramifications directed toward the east and south. These ramifications give rise to the radiation of Aristillus. They are sur-

mounted by an enormous quantity of peaks or basaltic columns which rise from their summits, and make them resemble from afar the multitude of bell towers that are seen on some Gothic cathedrals. Aristillus presents the general aspect of most of the mountains of our satellite.

Thus the Moon would appear very inhospitable to us. The sense of speech, like the sense of hearing, would be lost, and, consequently, would not exist. To the privation of these two senses, perhaps, must be added an inferiority in the pleasures which sight gives to us, seeing that, wherever the eye would be directed, it would only meet with white, rugged and sterile mountains, and lofty and deserted craters. These solitary and dried-up landscapes show how true were the lines of Alfred de Musset :

> "Va, Lune moribonde,
> Le beau corps de Phœbe
> La blonde
> Dans la mer est trombe
> Tu n'en es que la face,
> Et, deja tout ride,
> S'efface
> Ton front depossede."

This reminds me of what Fontenelle said regarding the changes at work on the surface of our satellite, caused, not by the movements of life, like those which regulate terrestrial nature, but by the simple falling down of lands. "Everything is in perpetual motion," he says ; "even including a certain young lady, who was seen in the Moon with a telescope about forty years ago, everything has considerably aged. She had a pretty good face, but her cheeks are now sunken, her nose is lengthened, her forehead and chin are now prominent to such an extent that all her charms have vanished, and I fear for her days."

"What are you relating to me now?" interrupted the marchioness.

"This is no jest," returned the author. "Astronomers perceived in the Moon a particular figure which had the aspect of a woman's head, which came forth from between the rocks, and then occurred some changes in this region. Some pieces of mountain fell, and disclosed three points which could only serve to compose a forehead, a nose, and an old woman's chin." I do not know whether the face, of which the ingenious writer speaks, existed anywhere but in his imagination ; but changes, even caused by simple fallings, are extremely rare, if even they are still produced. For a hundred years, for instance, during which period a day has not elapsed in which the Moon has been visible, without it being observed by the telescope, the slightest movement has never been noticed. At the commencement of the century, it is true, people fancied they observed active volcanoes, but they have since discovered that very probably what were then taken for volcanoes were nothing more than the white crests of certain mountains, their form or their structure being more favorably adapted to reflect light. Thus the orb of night remains dumb and silent, revolving in the heavens like a deserted planet.

Now that I have pointed out how the Moon is an inhospitable world, poor and destitute of nature's gifts, it is necessary to retrace my steps, and show it to you as a magnificent world, worthy our admiration and esteem. I do not wish to contradict my foregoing words ; but in order not to leave a bad impression with regard to our faithful friend, I wish to remind you that nature, even when it appears to disgrace some of its works from some points of view, favors them with very desirable riches when regarded under other aspects.

To an astronomer the Moon would be a magnificent observatory. In the daytime he could observe the stars at noon, and thus discover, without trouble, that they reside eternally in the heavens. With us, on the contrary, among the ancients, were a great number who imagined that they were lighted up in the evening and extinguished in the morning. If, then, people make astronomical observations on the Moon, the Sun is not a tyrant who governs the heavens absolutely ; it allows the stars to be enthroned peaceably with it in space ; and studies commenced during the night can be carried on without difficulty during the day until the following night. On our satellite the nights are fifteen times 24 hours long, and the days are of the same length ; but there is an essential difference to remark between the nights of the lunar hemisphere, which faces us, and those of the hemisphere which we do not see.

You must have noticed that the Moon always presents the same side to us. From the beginning of the world it has never shown but this side. We read in Plutarch, who wrote nearly two thousand years ago, a thousand conjectures relative to the side of the Moon forever turned toward us. Some said it was a large mirror, well polished and excellent, which sent back from afar the image of the Earth : the dark portions represented the oceans and seas, while the bright portions represented the continents. Others believed that the spots were forests, where some placed the hunts of Diana, and that the most brilliant parts were the plains. Others, again, saw in it a very light, celestial Earth ; they stated that its inhabitants must pity the Earth which is below them, and which is only a mass of mud. Others, again, and their singular opinion was widely spread, added that the beings who peopled it were fifteen times larger than those of our Earth, and by the side of the lunar trees our oaks would only be small bushes. All this to explain the nature of the lunar face eternally turned toward us.

Now, if we never see but one side of the Moon, it follows that there is only one side of this body which sees us ; so that half of the Moon has a moon—namely, our Earth—and the other half is deprived of one. If there are any inhabitants on the hemisphere turned from us, they do not guess that the Moon is only a body placed for the illumina-

tion of our nights, and they must be greatly astonished when the narratives of travellers relate to them the existence of our Earth in the heavens. If the travellers there resemble those here, what tales must they spread with regard to us! But, also, how useful must the Earth be to the lunar nights, and how beautiful we are—from afar! Fancy to yourself fourteen moons like that which gives us light, or, more properly speaking, a moon with fourteen times the extent of surface, and you will have an idea of the Earth as seen from the Moon. Sometimes it only presents a fringed crescent a few days after the new Earth; sometimes it presents the first quarter; sometimes it shines out with its full disk, spreading its silvered light in floods. The most fortunate thing is, that it begins to shine precisely in the evening, that its brightest light, its full disk, is precisely at midnight, and that it fades away in the morning, at the time when it is no longer required. And it is known that from the evening to the morning is fifteen times twenty-four hours with our neighbors the Selenites. How much more reasonable are these inhabitants than we are in believing that the Moon was created and placed in the world expressly for them, and that we are only their very humble servants!

In some aspects, then, the Moon appears much more favored than the Earth. But not in planetary importance, for it measures scarcely the quarter of the diameter of the Earth, 2,153 miles; its total surface is 14,568,000 square miles, including both hemispheres, that is to say, nearly the thirteenth part of the terrestrial surface; its volume is one forty-ninth of the volume of the terrestrial globe. This would probably not prevent its inhabitants (if there are any) from fancying themselves superior to us, and believing us to be their servants rather than their masters; for it is generally known that the smaller people are, the more vanity they possess. The inhabitants of the invisible hemisphere, have the most beautiful nights imaginable, and those who live on the visible hemisphere one of the most beautiful moons. Only the inhabitants of the first moons of Jupiter and Saturn would be able to claim the superiority of their respective planets. Never any clouds, never any tempests, come to disturb these lonely and silent nights; profound calm, unalterable peace, occupy these regions. Moreover, while we only know a portion of their world, ours, turning on its axis in twenty-four hours, is entirely unveiled to them, so that with good eyes or with optical instruments they are able to contemplate our Earth revolving over their heads, presenting to them in turn the different countries of our abode. There, the new world stained with cruel battles; further on, gloomy isles, where they sacrifice human heads to the serpent Vaudoux; here, Russia crushing Poland, who resists strongly; and to the left a small verdant spot, where thirty-eight millions of French regard in various ways a throne which rises up in the midst of a great city. And ourselves, we contemplate the pensive Moon in the stillness of night, hoping that its people and those of other worlds are more united than our family. Yes, beloved light of the solitary nights, we think that nature has given thee some compensation for the things of which thou art deprived, and that the unknown riches of thy abode would strangely surprise those who for thee would escape from our world. We have seen that thou hast no air, that thou hast not a drop of water to quench thy thirst; but that does not prevent us from returning to our old sympathy for thy beauty. If thou hast not the elements which suit us, if water and land, air and fire, do not reside in thy midst, thy nature is different, and thou art not less complete in thy creation.

Remain in the heavens of our reveries, renew those phases which form our months, pour out thy dew of light into the limpid air; the traveller will always love to choose thee as his guide in the midnight hours, in the paths of the sea, or in desert countries.

V.

ECLIPSES.

In the circle which it describes round the Earth, the Moon passes every fifteen days between the Sun and us—at the time of new moon—and every fifteen days it is on the opposite side of the Sun (the Earth being between it and the Sun); this is at the time of full moon. Now it happens, sometimes, that it passes exactly between us and the Sun, instead of passing a little above or below it, as it does in most cases. When this occurs, the light of the radiant body naturally finds itself stopped, in part or altogether, according as the lunar disk hides from us a part or the whole of the solar disk. There is, then, an eclipse of the Sun, either partial or total.

On the other hand, it happens sometimes that the Moon, passing behind the Earth, arrives just in the shadow which the Earth throws behind it, as every illuminated object does. When it is in this shadow it no longer receives the light of the Sun, and, as it only shines by this light, it loses its brightness. Its whole disk completely loses its light if it is wholly within the cone of the Earth's shadow; it remains half illuminated if, passing by the edge of the cone, it only half enters it. In these circumstances there is an eclipse of the Moon, either total or partial. Nothing, therefore, is so simple as an eclipse. When you have a lamp with a radiant globe before you, if you pass your hand before your eyes, you momentarily intercept the light which illumines you; to you it is an eclipse of the lamp by your hand. The same thing is produced when there happens on the Earth an eclipse of the Sun by the Moon. If, now, you turn round, leaving the lamp behind you, and again pass your illuminated hand before your face, it will be momentarily in the shadow of your body. This gives

an idea of what happens in an eclipse of the Moon, when it passses into the shadow of the Earth.

If the movements of the Moon were performed exactly in a plane, the prolongation of which passed through the Sun and Earth, there would be an eclipse of the Sun every new moon, and an eclipse of the Moon every full moon. But the orbit in which the Moon moves is inclined a little to this plane, and oscillates from one side to the other, so that eclipses are very variable in their number and magnitude. Nevertheless, this variety has its limits. There cannot be less than two eclipses a year, and not more than seven. When there are only two, they are both eclipses of the Moon. These phenomena return yearly in the same order at the end of eighteen years and ten days; a period known to the Greeks under the name of the Metonic Cycle, and which the Chinese themselves used more than three thousand years ago, to predict their eclipses.

However simple the cause of this phenomenon may be, now that it is known—and known causes are always so simple that one asks why they were never known before—however easy this explanation appears, for a long time the human race was astonished at the passing absence of the Sun's light during the day; for a long time it felt full of fear and disquietude before this unexplained wonder. The light of day was rapidly diminished, and suddenly disappeared without the sky being darkened by any cloud. Darkness instead of light, stars shining in the sky, nature seeming surprised and astonished; the combination of these unusual events is more than sufficient to explain the momentary terror with which individuals, and, indeed, whole nations, allowed themselves to be carried away in these solemn moments. By reason of the Moon's rapid motion, a total eclipse never lasts longer than five minutes; but this short period is sufficient to allow a thousand sentiments to succeed each other in the terrified mind. The disappearance of the light of the Moon sometimes caused great trouble to ignorant minds; with how much more reason would the disappearance of the orb of day cause inquietude and fear.

"History is full of the examples of fear caused by eclipses," says Francœur, "and dangers caused through ignorance and superstition." Nicias had resolved to leave Sicily with his army; but, frightened by an eclipse of the Moon, and wishing to delay several days, to assure himself if our satellite had lost nothing after this event, he missed the opportunity of retreat; his army was destroyed, he himself perished, and this misfortune commenced the ruin of Athens.

Often it has been seen that clever men have taken advantage of people's terror during eclipses, either of the Sun or the Moon, to gain their wishes. Christopher Columbus, reduced to sustaining his soldiers on the voluntary gifts of a savage and poor nation, and nearly losing this resource and perishing with hunger, gave out that he was about to deprive the world of the Moon's light. The eclipse began, terror seized the Indians, and they returned, bringing to the feet of Columbus the accustomed tribute.

Drusus appeased a sedition in his army by predicting an eclipse of the Moon; and, according to Livy, Sulpitius Gallus, in the war of Paulus Emilius against Perseus, used the same stratagem. Pericles, Agathocles, King of Syracuse, and Dionysius, King of Sicily, nearly fell victims to the ignorance of their soldiers. Alexander near Arbella, was obliged to use all his skill to calm the terror that an eclipse had cast over his troops. Thus it is that superior men, rather than sink under the circumstances which oppress them, exert their art, to turn them to their profit.

How many fables were built on the idea that eclipses were the effect of Divine wrath, which avenged the iniquities of man by depriving him of light! Sometimes Diana sought Endymion in the mountains of Caria; sometimes the magicians of Thessaly caused the Moon to fall on the herbs destined for enchantment.

Now it is a dragon which devours the Sun, and whole nations seek to frighten it away by cries; or it is supposed that God holds the Sun inclosed in a tube, and hides or shows us the light by means of a shutter, etc. The progress of science has proved the absurdity of these opinions and fears, since it is known to be possible to calculate by astronomical tables, and to predict a long time beforehand, the instant when the wrath of Heaven will burst forth. Nevertheless, not long ago this terror caused misfortunes in the army of Louis XIV. near Barcelona, at the time of the total eclipse of 1706; and the device of this monarch, *Nec pluribus impar*, has given rise to injurious allusions.

Biot gives us, in his "Etudes sur l'Astronomie Indienne et Chinoise," very curious details on the rites which presided and which still preside over the observation of the eclipses in the Celestial Empire. The emperor is considered to be the son of Heaven; and with this title his government ought to present the picture of the immutable order which governs the celestial movements. When the two great luminaries—the Sun and the Moon—instead of following their own routes separately, cross each other's paths, the regularity of the order of the heavens appears to be upset, and the disturbance which is there manifested must have its likeness, as well as the cause, in the disorders of the government of the emperor. An eclipse of the Sun was then considered as a warning given by Heaven to the emperor to examine his faults and correct them. When this phenomenon was announced beforehand by the appointed astronomer, the emperor and grandees of his court prepared themselves by fasting, and dressing themselves in garments of the greatest simplicity. On the appointed day the mandarins attended at the palace with bows and arrows. When the eclipse commenced, the emperor himself beat on the

drum of thunder the "*roulement du prodige*," to give the alarm; and at the same time the mandarins let fly their arrows toward the sky to aid the eclipsed body. Gaubil quotes these particulars from the ancient Book of Rites, and the principles are announced in the Tcheou-li. After this, the discontent that would be caused by an eclipse not taking place at the time predicted may be imagined; and likewise if one suddenly appeared without being predicted. In the first case, the whole ceremonial was found to have been uselessly prepared; and the desperate efforts which, in consequence of the want of preparation, were made in the second case, inevitably produced a disorderly scene compromising to the imperial majesty. Such errors, although so easily made, placed the poor astronomers in danger of losing their goods, their office, their honor, and sometimes their life. Such a disgrace happened in the year 721 of our era; the Emperor Hiouen-Tsong sent for a bronze Chinese, called Y-Hang, renowned for his knowledge of astronomy. After having shown himself very learned, he had the misfortune to predict two eclipses of the Sun, which were ordered to be observed throughout the whole empire. But no one saw anywhere on the appointed days any trace of an eclipse, although the sky was almost everywhere serene. To clear himself he published a work, in which he pretended that his calculation was exact, but that Heaven had changed its rules of movement—doubtless in consideration of the high virtues of the emperor. Thanks to his reputation, otherwise deserved—perhaps, also, to his flattery—he was pardoned.

The same ideas on the importance and signification of the Moon and Sun which existed with the Chinese more than four thousand years ago, remain at the present day, and are still powerful, causing the same demands; but they have become less perilous for astronomers, as these phenomena are now predicted several years in advance, with a mathematical certainty, in the great ephemerides of Europe and America, which can easily be procured. M. Stanislas Julien found in the *Recueil des Lois de Chine* the complete description of the ceremonies still prescribed and practised at the present day on this occasion. The following is a specimen:

"Every time that an eclipse of the sun occurs pieces of silk are attached to the door of the minister of the rites, called I-men; and in the great hall they place a table to burn the perfumes at the top of the tower called Lou-thai (tower of the Dew). The imperial guard places twenty-four drums on both sides, inside the door I-men; the Kiaofan-ste places musicians at the base of the tower, Lou-thai; he places also each magistrate in a part of the tower, at the spot where they must bow down to salute. All are turned toward the sun. When the president of astronomy has announced that the eclipse has begun, all the magistrates in court garments, arrange themselves and stand up. At a given signal they fall on their knees, and then the music begins.

"Each magistrate makes three prostrations and nine bows, after which the music stops. When the magistrates of the tribunal of the rites have finished offering the perfumes, all the others kneel down. The Kiaosse-Koran advances with a drum, which he strikes to release the sun. The president of the ministry of rites gives three beats of his drum, and then they all strike theirs together. When the president of the astronomical office has announced that the sun has recovered its circular form, the drums stop. Each magistrate kneels three times, and touches his head nine times on the earth. The music recommences; when these ceremonies are over, the music stops; then all the magistrates return each to his own side.

"When the moon is eclipsed they assemble in the office of the Ta -tch'ang (president of the ceremonies) and they observe the same rites for the deliverance of the moon as for the sun."

In civilized countries people no longer fear the arrival of eclipses, or think that eternal night is spreading over the Earth. It is known that these are celestial phenomena, studied and understood like many others, resulting from known movements and determined beforehand. They have entirely lost their supernatural character, and belong to a purely physical order of things. At the present time astronomers predict the eclipses of the Sun and Moon in the same manner as they have discovered past eclipses, by calculation, and have thus been able to assign more exactly certain dates in history. They know at what time the Moon will pass before the Sun, and will rob us of a portion, more or less great, of its light; and the proof is, that I can even now (in 1865) give you the times at which all the eclipses which will happen to the end of this century will occur. I will not give the list, and cover these pages with dates, but to convince you I will point out the total eclipses of the Sun, which will be visible at the places indicated until the year 1900. They are not numerous, as you see.

December 22, 1870, a total eclipse of the Sun at the Azores Islands, in the south of Spain and Italy, in Algeria and Turkey; August 19, 1889, a total eclipse of the Sun at the northeast of Spain, southern Russia, and central Asia; August 9, 1896, a total eclipse of the Sun in Siberia, Lapland, and Greenland; lastly, May 28, 1900, a total eclipse in the United States, Spain, Algeria, and Egypt.

I do not doubt but you will be a witness with me at the last one, and will thus be in a position to prove the truth of this prediction. Unfortunately, not one of them will be visible at London; but if our inventions with steam and electricity continue, and others come to their aid, the Earth will soon be but one country, and we shall travel from here to Pekin, as we did last century from Paris to St. Cloud.

In stating that the eclipses of the Sun and Moon are no longer a terror to us, I do not mean that they no longer make any impression. No; the sudden impressions caused by the spectacle of the rarest phenomena of nature are independent of our reflection, and the sudden absence of the solar light in the middle of the day produces in all beings an emotion from which they cannot free themselves. The narrative of the effect produced by eclipses on man, and even on animals, is too interesting not to be presented to you in concluding this chapter. I shall choose as

narrator an eye-witness of the total eclipse of July, 1842, whose talent is too well known for it to be praised; I refer to Arago, who thus gives us his impressions, enriched with other proofs, to which he attributes such high value as to place them with his own. (See "Popular Astronomy," Vol. III.)

"Riccioli relates, 'that during the total eclipse of 1415 birds were seen in Bohemia to fall down dead with fright.' The same is said relative to the eclipse of 1560: some eye-witnesses say, 'The birds, strange to say, fell to the ground, seized with fear.' In 1706, at Montpellier, the observer said, 'Bats flitted about as at the beginning of night. Fowls and pigeons ran precipitately to their roosts. The small birds that had been singing in their cages became silent, and put their heads under their wings. The animals employed in the labors of the field all at once halted.'

"The alarm occasioned among beasts of burden by the sudden transition from day to night is registered also in Louville's memoir relative to the eclipse of 1715, thus: 'Horses that were laboring or employed on the high roads lay down. They refused to advance.'

"Fontenelle relates that in the year 1654, at the mere announcement of a total eclipse, a multitude of the inhabitants of Paris hid themselves in deep cellars.

"Thanks to the progress of science, the total eclipse of 1842 found the public in a very different disposition from that which they manifested during the eclipse of 1654. A lively and legitimate curiosity had taken the place of puerile fears. The poorest villagers of the Alps and Pyrenees repaired in crowds to the places whence the phenomenon could be best seen; they did not doubt, with some rare exceptions, that the eclipse had been correctly announced; they regarded it as a natural, regular, and calculable event, about which good sense taught them not to be uneasy.

"At Perpignan, only persons who were confined to their chambers by ill-health remained at home. Early in the morning the terraces, the ramparts of the town, the hills outside, whence the sunrise could be best seen, were crowded. In the citadel, beside the numerous groups of citizens seated on the glacis, we had beneath us all the soldiers collected in a vast square to be reviewed. The time for the commencement of the eclipse was approaching. Nearly twenty thousand people, with smoked glasses in their hands, were examining the radiant orb projected on the azure sky. We had scarcely, though provided with powerful telescopes, begun to perceive a slight indentation in the Sun's western limb, when an immense shout, the commingling of twenty thousand different voices, proved that we had only anticipated by a few seconds the naked-eye observation of twenty thousand astronomers equipped for the occasion, and exulting in this their first trial. A curiosity, animated by the desire of not being outdone, seemed to have inspired the natural sight with an unusual degree of penetration and power.

"Between this time and that which just preceded the entire disappearance of the Sun, we did not remark anything in the countenances of the spectators, deserving of mention. But when the Sun, being reduced to a narrow filament, began to throw only a faint light on our horizon, a sort of uneasiness took possession of the mind, each person felt an urgent desire to communicate his emotions to those around him. Then followed a hollow moan resembling that of a distant sea after a storm, which increased as the slender crescent diminished. At last the crescent disappeared, darkness instantly followed, and this phase of the eclipse was marked by absolute silence, as distinctly as it was by the pendulum of the astronomical clock. The magnificence of the phenomenon had triumphed over the petulance of youth, over the levity affected by some of the spectators as indicative of mental superiority, over the noisy indifference usually professed by soldiers. A profound calm also reigned throughout the air; the birds had ceased to sing.

"After a solemn expectation for two minutes, transports of joy and frenzied applause spontaneously and unanimously saluted the return of the solar rays. The sadness produced by feelings of an undefinable nature was now succeeded by a lively satisfaction, which no one attempted to moderate or conceal. For the majority of the public the phenomenon had come to a close. The remaining phases of the eclipse had no longer any attentive spectators beyond those devoted to the study of astronomy.

"Even those who appeared to be most deeply moved at the instant of the sudden disappearance of the Sun, amused themselves the very next day, and to my mind unreasonably, with recounting the state of alarm into which many country people had been thrown. Such people, at any rate, made no secret of their feelings. As for myself, I thought it very natural that illiterate persons, who had not been informed by anybody that an eclipse would occur on the morning of the 8th of July, should feel great uneasiness on seeing utter darkness so instantly follow daylight. Let it not be supposed that the idea of a convulsion of nature, the idea that the world was immediately coming to an end, is what would most generally disturb the minds of a rude and simple people. When I questioned them as to the true cause of the despair which had taken possession of them on the 8th of July, they immediately replied, "The sky was serene, and yet the light of day diminished, and every object grew shadowy, and then all at once we were in the dark. We thought that we had become blind."

We extract from the *Journal des Basses Alpes*, of July 9, 1842, the following anecdote, which seems to me to be worthy of preservation:

"A poor child in the commune of Sieges was watch

ing his flock entirely ignorant of the approaching event; he became uneasy on seeing the sun gradually become dark; for no cloud, no vapor, accounted for the change. When the light suddenly disappeared, the poor child, overcome with fright, took to crying and called for help! His tears were still falling when the sun again sent forth a ray of light. Reassured by the commencement, the boy crossed his hands, exclaiming in the *patois* of the district, 'O beautiful sun!'" (O beou souleou!)

Arago afterward points out several curious facts on the influence of eclipses on animals:

"An inhabitant of Perpignan purposely kept his dog without food from the evening of the 7th of July. The next morning, at the instant when the total eclipse was going to take place, he thrw a piece of bread to the poor animal, which had begun to devour it when the sun's last rays disappeared. Instantly the dog let the bread fall, nor did he take it up again for two minutes, that is, until the total obscuration had ceased, and then he ate it with great avidity.

"Another dog sought refuge between his master's legs when the sun became eclipsed. In a farm, some fowls at the instant of total obscuration, suddenly left the millet that had just been given them, and sought refuge in a stable. At the Mas de l'Asparron, the fowls being far from any habitation, went and grouped themselves under a horse's belly. A hen attended by a brood of chickens hastily called them to her, and covered them with her wings. Some ducks which were swimming about in a pool at the instant of the sun's disappearance, did not attempt to regain the farm which they had left two hours before, but huddled together in a corner.

"At La Tour, chief town of the canton, in the Eastern Pyrenees, an inhabitant had three hen linnets. On the 8th of July, very early in the morning, on hanging the cage up in the drawing-room, he remarked that the birds looked very well; after the eclipse one of them was found to be dead. Are we to suppose that the linnet in its fright hit itself violently against the bars of the cage? Some facts observed elsewhere tend to render this supposition probable."

Even insects did not escape a like impression.

M. Lentheric, professor at Montpellier, also gave some details concerning the effects of the total eclipse upon several species of animals. The bats, thinking night had come, quitted their retreats; an owl came out of St. Peter's tower, and flew across the square of the Peyrou; the swallows disappeared; the fowls went to roost; some oxen who were feeding freely near the church of Maguelonne arranged themselves in a circle with their backs toward each other, and their horns outward, as if to resist an attack.

Some observers at Cremona say that an immense number of birds fell to the ground; and M. Zamboni, the author of the "Piles Séches," is quoted as having seen a sparrow fall beside him. M. Piola, who was under a tree near Lodi, remarked that the birds ceased tossing during the moments of darkness, but none fell.

In a narrative that Father Zantedeschi addressed to Arago from Venice he said that

"Some birds wishing to escape and not being able to see, knocked up against the chimneys and the walls with such violence as to fall down stupefied on the roofs, in the streets, and into the lagoons. Among the birds that met with these accidents may be specified some swallows and a pigeon. Other swallows were seized in the streets, their fright having scarcely left them the power of fluttering.

"Some bees which had left their hive in great numbers at sunrise, returned to it even before the instant of total darkness; and they waited till the sun had entirely resumed its brightness before they ventured forth again."

These narratives give a sufficient idea of the effect produced by unusual phenomena on the faculties of men and animals. The necessity of order is so deeply attached to creation that an appearance of trouble throws us out of our normal security, and fills us with fear.

BOOK FIFTH.

I.

THE PLURALITY OF INHABITED WORLDS.

THE astronomical truths which have been the subject of our conversation, doubtless prove the high character of the human mind which aspires to them, and which, scrutinizing the organized laws of the universe, has been able to determine the causes which regulate the harmony of the cosmos and secure its perpetuity. No doubt, it is good for man, this spiritual atom inhabiting a material atom, to have penetrated the mysteries of creation, and to have been exalted to the knowledge of these sublime heights, the contemplation of which alone overwhelms and annihilates him. But if the universe remains to man only a great material mechanism, moved by physical forces, if nature is nothing in his eyes but a gigantic laboratory, where the elements are mingled blindly under the most various and casual forms; in a word, if this admirable and magnificent science of the heavens confines the efforts of the human mind eternally to the geometry of the heavenly bodies, the science would never attain its real end, and it would stop at the moment of reaping the fruit of its immense labors. It would remain supremely incomplete if the universe were never anything to it but an assemblage of inert bodies floating in space under the action of material forces.

The philosopher must go farther. He must not confine himself to seeing under a more or less distinct form the great body of nature. But, stretching forth the hand, he must feel under the material envelope, the life which circulates in great waves. God's empire is not the empire of death; it is the empire of life.

We live on a world which is no exception among the heavenly bodies, and which has not received the least privilege. It is the third of the planets which revolve round the Sun and one of the smallest among them, without going beyond our system, other planets are much more important than it; Jupiter, for instance, is 1414 times greater, and Saturn 734 times. While it appears to us the most important of the universe, it is in reality lost in the immensity of the worlds which people the heavens, and the whole creation does not guess at its existence.

Of the planets of our own system there are only four, the inhabitants of which can know that the Earth exists; these are, Mercury, Venus, Mars, and Jupiter; and even to this last one it is most of the time invisible in the solar aureola. Now, while the

Earth is thus lost amid worlds more important than itself, the other worlds are in the same conditions of habitability as those that we observe on the Earth. On these planets, as on our own, the generous rays of the Sun pour forth heat and light; on them, as here, years, months, and days succeed each other, drawing with them the seasons which, from time to time, support the conditions of existence; on them as here, a transparent atmosphere envelopes the inhabited surface with a protecting climate, gives rise to meteoric movements, and develops those ravishing beauties which celebrate sunrise and sunset. On them as here, vaporous clouds rise from the ocean with the deep waves, and spreading themselves under the heaven, carry dew to the parched-up regions. This great movement of life which circulates over the Earth is not confined to this little planet; the same causes develop elsewhere the same effects, and on many among these strange worlds, far from noticing the absence of the riches with which the Earth is endowed, an abundance of wealth of which our abode only possesses the first-fruits is observed. By the side of these bodies, the Earth is essentially an inferior world in many respects; from the unsatisfactory conditions of geological stability of which the terrestrial spheroid reminds us, its surface being only a thin pellicle, to the fatal laws which govern life on this Earth where death reigns supreme.

If, on the one hand, the other worlds have conditions of habitability quite as powerful, if not more so, as the terrestrial conditions, on the other hand, the Earth, considered in itself, appears to us like an overflowing cup whence life issues on all sides. It seems that to create is so necessary to the order of nature, that the smallest piece of matter of suitable properties does not exist without serving as an abode of living beings. While the telescope discovered in the heavens fresh fields for creation, the microscope showed us below the range of visibility the field of invisible life, and that, not content with spreading life everywhere where there is matter to receive it, from the primitive period when this globe had scarcely left its fiery cradle, to our days, nature still heaps up existence, to the detriment of existence itself.

Leaves of plants are fields of microscopical flocks of which certain species, although invisible to the naked eye, are real elephants beside other beings, whose extreme diminutiveness has not prevented an admirable system of organization for the carrying on of their ephemeral life. Animals themselves serve as an abode to races of parasites which, in their turn, are themselves the abode of parasites still smaller. Under another aspect the infinity of life presents a correlative character in its diversity. Its force is so powerful that no element appears capable of struggling advantageously against it, and tending to spread itself in every place, nothing can stop its action. From the high regions of the air, where the winds carry the germs, to the oceanic depths, where they undergo a pressure equal to several hundred atmospheres, and where the most complete night extends its eternal sovereignty; from the burning climate of the equator and the hot sources of volcanic regions to the icy regions and the solid seas of the polar circle, life extends its empire like an immense network, surrounding the whole Earth, amusing itself with all obstacles, and passing over all abysses, so that there is not in the world any district which can pretend to be beyond its absolute sovereignty.

It is by studies founded on this double consideration, the insignificance of the Earth in creation, and the abundance of life on its surface, that we are able to raise ourselves to the first real principles on which the demonstration of the universal habitation of the heavenly bodies must be fixed. For a long time man could confine himself to the study of phenomena; for a long time he must still keep to the direct and simple observation of physical appearances, in order that science may acquire the precision which constitutes its value. But now this entrance of truth can be passed, and thought, outstripping matter, may rise to the idea of intellectual things. In the bosom of these distant worlds, it sees universal life plunging its immense roots; and at their surface it sees this life spreading itself, and intelligence establishing its throne.

Founded on the astronomical basis, the only possible foundation, researches made in the domain of the physical sciences, from celestial mechanism to biology, and in that of the philosophical science from ontology to morals, the old idea of the plurality of worlds has risen to the rank of a doctrine. The evidence of this truth has been revealed to the eyes of all those who are impartially and entirely given up to the study of nature. It does not come within the bounds of this discourse to enter fully on this philosophical aspect of creation; but if I consider it in itself as the logical conclusion of astronomical studies, I owe it to my readers at least to offer them as a modest conclusion of the narratives which they have followed up to this time, the principal results to which we have arrived on this great and beautiful question of the existence of life on the surface of the heavenly bodies.

In the first place, the following is the first consideration established on the astronomical character of the world and its history: If the reader follow the philosophical march of modern astronomy, he will discover that from the moment when the movement of the Earth and the volume of the Sun were known, astronomers and philosophers found it strange that a body so magnificent was solely employed to light up and warm a little imperceptible world, arranged in company with many others under a supreme rule. The absurdity of such an opinion was still more striking, when they found that Venus was a planet of the same dimensions as the Earth, with

mountains and plains, seasons and years, days and nights, similar to our own; the analogy was extended to the conclusion that these two worlds, similar in their formation, were also similar in their *rôle* in the universe; if Venus was without population, the Earth ought to be equally so; and conversely, if the Earth was peopled Venus must be so also. But afterward, when the gigantic worlds of Jupiter and Saturn were observed, surrounded with their splendid retinues, they were compelled to refuse living beings to the preceding little planets, if they did not equally endow these, and moreover give to Jupiter and Saturn men much superior to those of Venus and the Earth. And indeed, it is not evident that the absurdity of the immovability of the Earth has been perpetuated a thousand times more extravagantly in this ill-conceived final causation, the object of which is to place our globe in the first rank of celestial bodies? Is it not evident that this world has been thrown without any distinction into the planetary cluster, and that it is not better adapted than the others to be the exclusive seat of life and intelligence? How little founded is the sentiment which animates us when we fancy that the universe is created for us, poor beings lost on a world, and that if we should disappear from the scene, this vast universe would be marred, like an assemblage of inert bodies, and deprived of light! If on the morrow not one of us was to awake, and if the night which, in each diurnal period enwraps the world, forever sealed the closed eyelids of all living beings, is it to be believed that henceforth the Sun would no longer pour out its light and heat, and that the powers of nature would cease their eternal movements? No; these distant worlds that we have just reviewed, would continue the cycle of their existence, rocked on the permanent forces of gravaitation, and bathed in the luminous aureola that the orb of day produces round its brilliant focus. The Earth that we inhabit is only one of the smallest bodies grouped round this focus, and its degree of habitation has nothing which distinguishes it amid its companions. For an instant place yourself at a distance in space whence you can embrace the whole solar system, and suppose that the planet in which you saw light is unknown to you. For to give yourself freely to the present study you must no longer consider the Earth as your country, or prefer it to other abodes; and then contemplate without pretension and with an ultra-terrestrial eye the planetary worlds which circulate round the focus of our life! If you suspect the phenomena of existence, if you imagine that certain planets are inhabited, if you are taught that life has chosen certain worlds in which to spread the germs of its productions, do you intend to people this small globe of the Earth, before having established in superior worlds the wonders of living creation? Or if you have the intention of settling yourself on a body whence you can embrace the splendor of the heavens, and on which you can enjoy the benefits of a rich and fertile nature, shall you choose as an abode this mean Earth which is eclipsed by so many resplendent spheres? In reply, reader, and it is the least strong and most rigorous conclusion that we can draw from the preceding considerations, let us agree that "the Earth has no marked pre-eminence in the solar system to entitle it to be the only inhabited world, and that, astronomically speaking, the other planets are arranged as well as it is as abodes of life."

A second consideration, founded on the varieties of living beings on the surface of the terrestrial globe, on the infinite power of nature, that no obstacle has ever stopped, and on the eloquent spectacle of the infinity of life itself in the terrestrial world, conducts the argument into a new order of ideas: "Nature knows the secret of all things, puts into action the most feeble as well as the most powerful forces, renders all its creations answerable, and constitutes beings according to the worlds and ages, without the one or the other being able to place any obstacle in the way of the manifestation of its power. Hence it follows that the habitability and habitation of the planets are a necessary complement to their existence, and that of all the conditions enumerated, not one can stop the manifestation of life on each of these worlds. But let us add another observation which will complete the preceding; let us think for an instant of our forced ignorance in this little isle of the great archipelago where destiny has bound us, and of the difficulty we experience in searching into the secrets and power of nature. Let us prove that, on the one hand, we do not know all the causes which have been able to influence, and which still influence, the manifestation of life, its support and propagation on the surface of the Earth; and that, on the other hand, we are still far from knowing all the principles of existence which propagate in other worlds very dissimilar creations. Scarcely have we penetrated those which regulate the daily functions of life; scarcely have we been able to study the physical properties of the media, the action of light and electricity, the effects of heat and magnetism. There exist others which go on constantly under our eyes, and which have not yet been studied nor even discovered. How vain then would it be to wish to oppose to the possibility of planetary existences the superficial and narrow principles of what we call our sciences? What cause would be able to struggle with advantage against the effective power of nature, and to place obstacles to the existence of beings on all these magnificent globes which revolve round the Sun! What extravagance to regard the little world where we first saw light as the only temple, or as the model of nature!"

Impressed with the value of the providen-

tial design of creation, these considerations become more imperious still. "That our planet was made to be lived in, is incontestible, not only because the beings which people it are here under our eyes, but again because the connection which exists between these beings and the regions in which they live brings the inevitable conclusion that the idea of habitation is immediately connected with the idea of habitability. Now this fact is an argument in our favor; for, unless we consider the creative power as illogical, or as inconsistent with its real manner of acting, it must be understood that the habitability of the planets imperiously demands their habitation. To what end have they received years, seasons, months, days; and why does not life come forth on the surface of these worlds which enjoy, like ours, the benefits of nature, and which receive, like ours, the rays of the same sun? Why these snows of Mars, which melt each spring, and descend to water its continents? Why these clouds of Jupiter, which spread shade and freshness over its immense plains? Why this atmosphere of Venus, which bathes its valleys and mountains? O splendid worlds, which float afar from us in the heavens! Would it be possible that cold sterility was ever the immutable sovereign of yonder desolate regions? Would it be possible that this magnificence, which seems to be your appanage, was given to solitary and bare worlds, where the lonely rocks eternally regard each other in sullen silence? Fearful spectacle in its immense immutability; and more incomprehensible than if Death had passed over the Earth in fury, and with a single stroke mowed down the living population which enlightens its surface, thus enveloping in one ruin all the children of life, and leaving it to roll in space like a corpse in an eternal tomb!"

Thus it is that, under whatever aspect we regard creation, the doctrine of the plurality of inhabited worlds is formed and presented as the only explanation of the final end—as the justification of the existence of material forms—as the crowning of astronomical truths. The summary conclusions which we have just quoted are established, logically and without difficulty, by observed facts; and when, having contemplated the universe under its different aspects, the mind is astonished at not having sooner conceived this striking truth, it feels within itself that the demonstration of such evidence is no longer necessary, and that it ought to accept it, even with no other reasons in its favor than the condition of the terrestrial atom compared with the rest of the immense universe. Humbled by this spectacle, one can but proclaim the luminous truth in a transport, disdaining all researches.

"Ah! if our sight was piercing enough to discover, where we only see brilliant points on the black background of the sky, resplendent suns which revolve in the expanse, and the inhabited worlds which follow them in their path, if it were given to us to embrace in a general *coup d'œil* these myriads of fire-based systems; and if, advancing with the velocity of light, we could traverse from century to century, this unlimited number of suns and spheres, without ever meeting any limit to this prodigious immensity where God brings forth worlds and beings: looking behind, but no longer knowing in what part of the infinite to find this grain of dust called the Earth, we should stop fascinated and confounded by such a spectacle, and uniting our voice to the concert of universal nature we should say from the depths of our soul: Almighty God! how senseless we were to believe that there was nothing beyond the Earth, and that our abode alone possessed the privilege of reflecting Thy greatness and power!"

II.

THE CONTEMPLATION OF THE HEAVENS.

How beautiful and worthy of the human mind is this contemplation of the visible splendors of creation! How much superior are these studies to the common preoccupations which occupy our days and pass away our years! How they elevate the soul toward real greatness! In the artificial world that we have formed for ourselves by our citizen habits, we have become so strange to nature that when we return to it we appear to enter into a new world. We have lost belief in its value, and thus deprive ourselves of the purest joys. By freeing ourselves from stormy life, by returning to peace we undergo a hitherto unknown impression, as if the sphere of harmony into which we enter had always remained far from the labors of our minds.

Studies of nature possess this precious characteristic, that being applied to truth, they récall us to our origin, to our material cradle. Worldly life is a real exile for the soul. Imperceptibly we get accustomed to content ourselves with appearances, no longer to seek the bottom and the substance of things. Imperceptibly we lose our value and greatness, when rocked on the surface of this unfathomable ocean on which float human barks. The objects which surround us alone attract our attention, and we forget the past like the future. But there are hours of solitude, when the soul, returning to itself, feels the emptiness of all these appearances, when it discovers how little they can satisfy it, when it anxiously searches and returns with love to real greatness alone, capable of giving firm ground for its repose, instead of the fluctuations which have agitated it. Then the soul has homesickness; it demands the truth; it wishes for the beautiful, and bids adieu to transient affections. If it is allowed at these hours of reflection to contemplate the beauties of nature; to admire and understand the wonders of creation; entirely giving itself up to the contemplation which captivates it, abandoning itself to the charm of the splendors studied, it devotes itself unreservedly to the spectacle which absorbs it.

forgetful of the false joys of the Earth, and eager after the true and profound ones which Nature, that young mother whose age is unchangeable, pours into the souls of the children who cherish her. The beauties of the heavens will captivate it with their charms, it will demand that such a contemplation shall never cease, that the night shall reveal to it wonder upon wonder, and that it may permitted not to leave the scene before its admiration is satisfied.

When we give our minds up to these high and magnificent studies we soon feel the great harmony, the admirable unity in which all things are bound together; we feel that all creation is one, that we form a constituent part of it, and that an immense life, scarcely guessed at, envelopes us. Then all phenomena take their place in the universal concert.

The golden star which shines in the depths of the heavens and the little grain of crystallized sand which reflects the solar ray, unite their light; the majestic sphere which revolves harmoniously in its gigantic orbit and the little bird which sings under the leaves; the immense nebula which arranges its system of suns in the vast expanse, and the bee-hive which receives the rhomboids of a republic in eternal concord; gravitation which bears up in space these formidable globes and these systems of worlds, and the humble zephyr which wafts beloved perfumes from one flower to another; great phenomena and imperceptible actions unite with each other in the general movement, and the infinitely great and the infinitely small embrace each other. For the universe is the action of a single thought.

No human speech, no work formed by the hand of man, can compete with the harmony of nature or the work of creation. Compare for an instant the most admirable *chef d'œuvre* among the wonders of art with the most simple among the productions of nature. As was said long ago, compare the richness of regal ornaments, the oriental tissue of Solomon's garments when in all his glory, the golden plates of his temple, the mosaics of his palaces, to the whiteness of the lilies, the bloom of the roses, and seek if the comparison can be thought of for an instant. The great characteristic which distinguishes these works, is that in the one, a restricted power marks the limits of its skill, while in the other the impress of an infinite power always remains. Magnify the power of our senses, take that astonishing lens which raises up giants where the most insignificant beings remained invisible; at its focus, the finest tissue, the most delicate work of human art is changed into a shapeless and coarse object; on the other hand, the most modest tissue formed by the hands of nature reveals hidden riches in proportion as the magnifying power increases.

Try now to compare our most wonderful instruments, from our formidable machinery which holds captive those powerful forces of which man has made himself master, to those exact instruments, so elegant, so sensitive with the untamable forces with which matter is animated, or with those admirable and precise laws which rule in an incomprehensible perfection the harmonious movements of the starry spheres at the concert of the heavens, and say how much art is surpassed by nature.

And the work of nature is charming in the infinitely small as in the infinitely great. The sublime spectacles which the contemplation of the heavens unveil to us are doubtless the most striking, the magnificence of which imposes itself most impressively on our astonished mind; but if we examined little things our imagination will remain confounded before them as before the greatest. On the poor little white butterfly which, born yesterday, will be in dust before to-morrow has passed, the analyzing eye of the microscope will show magnificent feathers of snowy white or dead yellow, symmetrically arranged, with as much care as those of the eagle intended to fly to the heavens; nevertheless to the naked eye there is nothing but an impalpable dust, which adheres to the fingers. On its head you may count twenty thousand eyes. If the finer drops of dew suspended at sunrise to the leaves of the lower branches, fall at the touch of a passing bird, you will see painted on this fine rain a rainbow not less rich than the gigantic arch uplifted at the end of a storm in the regions of the atmosphere; charming little rainbow, formed for a life of a few tenths of a second and disappearing as it was born. Examine these humble wild flowers with colored petals; emeralds and rubies succeed each other, gold and sapphire intermingle their delicate tints; it is in miniature the same magnificence of colors as shines in the double stars. We could continue without limit these comparisons, which prove to us, in all directions, the infinity of the creative power.

Nevertheless we do not think of it, and we pass indifferently by these wonders. If the night was deprived of stars, said a philosopher, and there was only one place on the Earth whence the constellations and bodies would be visible, the pilgrimage to this place would never cease, and each would wish to admire these wonders. But that which daily surrounds us loses its value, custom destroys attention, and we forget nature for pleasures certainly infinitely less worthy of our thoughts. If sometimes we allow ourselves to be exalted by these wonders of the science of the heavens, we quickly return to the things of the world, forgetting our grand questions. The Earth has the gift of captivating us so strongly that we willingly forget the heavens for it.

Let us consider, dream, and think sometimes of the beautiful in nature. Let us allow ourselves to be drawn away by those delicious reveries which carry us from earthly tumults to calm and silence. Let us ascend to that limpid source, whence descend all consolation in sadness, all coolness after the fatigue of the day, all peace in disquietude. When our lips are parched by the winds of the world, let us moisten them at this clear spring, let us ask a kiss from the lips of Nature—and may this pure aspiration keep us from poisoned cups.

The fulness and height of man's happiness, said Seneca, is to tread under foot all bad desires, to dive into the heavens, and to penetrate the most hidden folds of nature. With what satisfaction, when our thought has taken flight from the midst of these, does it mock at the mosaics of our riches, and our earth with all its gold! To disdain these porticoes—these brilliant platforms of ivory—these rivers running through palaces—one must have embraced the circle of the universe, and looked from on high on this narrow globe, a great portion of which is submerged, while that which is above water is either savage, or torrid, or frozen. This is, then, says the sage, the spot divided among many nations with fire and sword! Here are our mortals, with their absurd frontiers! If the human intelligence were given to ants, would they not also divide a square of garden into several provinces? When thou shalt have risen to the really grand objects of which I speak, each time that thou shalt see armies marching with colors raised, and as if it were a serious matter, horsemen sometimes flying unguardedly, or retreating on their supports, thou wilt be tempted to say, "These are evolutions of ants—great movements in little space." Oh, how little is man if he does not rise above human things! There are regions above, without limits, which our soul as admitted to possess, provided that it carries away with it the least possible that is material, and that, being purified from all stain, and free from fetters it is worthy of flying thither. As soon as it reaches there, it is nourished and developed; it is as if delivered from its irons, and returned to its source: it recognizes itself to be a daughter of heaven from the delight it takes in celestial things; it enters there not as a stranger, but as if at home. An eager spectator, there is nothing but it sounds and interrogates. Ah! who could hinder it? Does it not know that all this is its domain? Man does not live on bread alone—he requires thought. It is on rising to these noble contemplations that he becomes worthy of his rank; it is by occupying his mind with these beautiful and fertile subjects of study that his countenance will preserve the divine expression of his destiny, and will shine more and more. Let us not forget the teachings of the night, but return sometimes to meditate under its silent gloom. Instead of a passing reverie, now that we have partly lifted the veil which hid the celestial mysteries from us, our minds will have an object better understood; we shall understand what we admire and we shall better appreciate these distant creations. These nocturnal hours will have a double value in our eyes, as they will place us henceforth in communication with worlds whose natures are no longer unknown to us. And it is with greater intimacy that we shall address that salutation to the Night, with which we opened our interview with the heavens:

"O Nuit! que ton langage est sublime pour moi,
Lorsque seul et pensif, assui calme que toi,
Contemplant les soleils dont ta robe est paree,
J'erre et medite en paix sous ton ombre sacree!"

THE END.

CONTENTS.

THE EVOLUTIONIST AT LARGE

By GRANT ALLEN

PREFACE.

These essays originally appeared in the columns of the *St. James's Gazette*, and I have to thank the courtesy of the editor for kind permission to republish them. My object in writing them was to make the general principles and methods of evolutionists a little more familiar to unscientific readers. Biologists usually deal with those underlying points of structure which are most really important, and on which all technical discussion must necessarily be based. But ordinary people care little for such minute anatomical and physiological details. They cannot be expected to interest themselves in the *flexor pollicis longus*, or the *hippocampus major*, about whose very existence they are ignorant, and whose names suggest to them nothing but unpleasant ideas. What they want to find out is how the outward and visible forms of plants and animals were produced. They would much rather learn why birds have feathers than why they have a keeled sternum ; and they think the origin of bright flowers far more attractive than the origin of monocotyledonous seeds or exogenous stems. It is with these surface questions of obvious outward appearance that I have attempted to deal in this little series. My plan is to take a simple and well-known natural object, and give such an explanation as evolutionary principles afford of its most striking external features. A strawberry, a snail-shell, a tadpole, a bird, a wayside flower—these are the sort of things which I have tried to explain. If I have not gone very deep, I hope at least that I have suggested in simple language the right way to go to work.

I must make an apology for the form in which the essays are cast, so far as regards the apparent egotism of the first person. When they appeared anonymously in the columns of a daily paper, this air of personality was not so obtrusive : now that they reappear under my own name, I fear it may prove somewhat too marked. Nevertheless, to cut out the personal pronoun would be to destroy the whole machinery of the work : so I have reluctantly decided to retain it, only begging the reader to bear in mind that the *I* of the essays is not a real personage, but the singular number of the editorial *we*.

I have made a few alterations and corrections in some of the papers, so as to bring the statements into closer accordance with scientific accuracy. At the same time, I should like to add that

I have intentionally simplified the scientific facts as far as possible. Thus, instead of saying that the groundsel is a composite, I have said that it is a daisy by family; and instead of saying that the ascidian larva belongs to the sub-kingdom Chordata, I have said that it is a first cousin of the tadpole. For these simplifications, I hope technical biologists will pardon me. After all, if you wish to be understood, it is best to speak to people in words whose meanings they know. Definite and accurate terminology is necessary to express definite and accurate knowledge; but one may use vague expressions where the definite ones would convey no ideas.

G. A.

I.

MICROSCOPIC BRAINS.

SITTING on this little rounded boss of gneiss beside the path which cuts obliquely through the meadow, I am engaged in watching a brigade of ants out on foraging duty, and intent on securing for the nest three whole segments of a deceased earthworm. They look for all the world like those busy companies one sees in the Egyptian wall-paintings, dragging home a huge granite colossus by sheer force of bone and sinew. Every muscle in their tiny bodies is strained to the utmost as they prise themselves laboriously against the great boulders which strew the path, and which are known to our Brobdingnagian intelligence as grains of sand. Besides the workers themselves, a whole battalion of stragglers runs to and fro upon the broad line which leads to the headquarters of the community. The province of these stragglers, who seem so busy doing nothing, probably consists in keeping communications open, and encouraging the sturdy pullers by occasional relays of fresh workmen. I often wish that I could for a while get inside those tiny brains, and see, or rather smell, the world as ants do. For there can be little doubt that to these brave little carnivores here the universe is chiefly known as a collective bundle of odors, simultaneous or consecutive. As our world is mainly a world of visible objects, theirs, I believe, is mainly a world of olfactible things.

In the head of every one of these little creatures is something that we may fairly call a brain. Of course most insects have no real brains; the nerve-substance in their heads is a mere collection of ill-arranged ganglia, directly connected with their organs of sense. Whatever man may be, an earwig at least is a conscious, or rather a semi-conscious, automaton. He has just a few knots of nerve-cells in his little pate, each of which leads straight from his dim eye or his vague ear or his indefinite organs of taste; and his muscles obey the promptings of external sensations without possibility of hesitation or consideration, as mechanically as the valve of a steam-engine obeys the governor-balls. You may say of him truly, "Nihil est in intellectu quod non fuerit in sensu;" and you need not even add the Leibnitzian saving clause, "nisi ipse intellectus;" for the poor soul's intellect is wholly deficient, and the senses alone make up all that there is of him, subjectively considered. But it is not so with the highest insects. They have something which truly answers to the real brain of men, apes, and dogs, to the cerebral hemispheres and the cerebellum which are superadded in us mammals upon the simple sense-centres of lower creatures. Besides the eye, with its optic nerve and optic perceptive organs—besides the ear, with its similar mechanism — we mammalian lords of creation have a higher and more genuine brain, which collects and compares the information given to the senses, and sends down the appropriate messages to the muscles accordingly. Now, bees and flies and ants have got much the same sort of arrangement, on a smaller scale, within their tiny heads. On top of the little knots which do duty as nerve-centres for their eyes and mouths, stand two stalked bits of nervous matter, whose duty is analogous to that of our own brains. And that is why these three sorts of insects think and reason so much more intellectually than beetles or butterflies, and why the larger

part of them have organized their domestic arrangements on such an excellent co-operative plan.

We know well enough what forms the main material of thought with bees and flies, and that is visible objects. For you must think about *something* if you think at all; and you can hardly imagine a contemplative blow-fly setting itself down to reflect, like a Hindu devotee, on the syllable Om, or on the oneness of existence. Abstract ideas are not likely to play a large part in apian consciousness. A bee has a very perfect eye, and with this eye it can see not only form, but also color, as Sir John Lubbock's experiments have shown us. The information which it gets through its eye, coupled with other ideas derived from touch, smell, and taste, no doubt makes up the main thinkable and knowable universe as it reveals itself to the apian intelligence. To ourselves and to bees alike the world is, on the whole, a colored picture, with the notions of distance and solidity thrown in by touch and muscular effort; but sight undoubtedly plays the first part in forming our total conception of things generally.

What, however, forms the thinkable universe of these little ants running to and fro so eagerly at my feet? That is a question which used long to puzzle me in my afternoon walks. The ant has a brain and an intelligence, but that brain and that intelligence must have been developed out of *something*. *Ex nihilo nihil fit.* You cannot think and know if you have nothing to think about. The intelligence of the bee and the fly was evolved in the course of their flying about and looking at things: the more they flew, and the more they saw, the more they knew; and the more brain they got to think with. But the ant does not generally fly, and, as with most comparatively unlocomotive animals, its sight is bad. True, the winged males and females have retained in part the usual sharp eyes of their class—for they are first cousins to the bees—and they also possess three little eyelets or *ocelli*, which are wanting to the wingless neuters. Without these they would never have found one another in their courtship, and they would have run their heads against the nearest tree, or rushed down the gaping throat of the first expectant swallow, and so effectually extinguished their race. Flying animals cannot do without eyes, and they always possess the most highly developed vision of any living creatures. But the wingless neuters are almost blind—in some species quite so; and Sir John Lubbock has shown that their appreciation of color is mostly confined to an aversion to red light, and a comparative endurance of blue. Moreover, they are apparently deaf, and most of their other senses seem little developed. What can be the raw material on which that pin's head of a brain sets itself working? For, small as it is, it is a wonderful organ of intellect; and though Sir John Lubbock has shown us all too decisively that the originality and inventive genius of ants have been sadly overrated by Solomon and others, yet Darwin is probably right none the less in saying that no more marvellous atom of matter exists in the universe than this same wee lump of microscopic nerve-substance.

My dog Grip, running about on the path there, with his nose to the ground, and sniffing at every stick and stone he meets on his way, gives us the clew to solve the problem. Grip, as Professor Croom Robertson suggests, seems capable of extracting a separate and distinguishable smell from everything. I have only to shy a stone on the beach among a thousand other stones, and my dog, like a well-bred retriever as he is, selects and brings back to me that individual stone from all the stones around, by exercise of his nose alone. It is plain that Grip's world is not merely a world of sights, but a world of smells as well. He not only smells smells, but he remembers smells, he thinks smells, he even dreams smells, as you may see by his sniffing and growling in his sleep. Now, if I were to cut open Grip's head (which Heaven forfend), I should find in it a correspondingly big smell-nerve and smell-centre—an olfactory lobe, as the anato-

mists say. All the accumulated nasal experiences of his ancestors have made that lobe enormously developed. But in a man's head you would find a very large and fine optic centre, and only a mere shrivelled relic to represent the olfactory lobes. You and I and our ancestors have had but little occasion for sniffing and scenting ; our sight and our touch have done duty as chief intelligencers from the outer world ; and the nerves of smell, with their connected centres, have withered away to the degenerate condition in which they now are. Consequently, smell plays but a small part in our thought and our memories. The world that we know is chiefly a world of sights and touches. But in the brain of dog, or deer, or antelope, smell is a prevailing faculty ; it colors all their ideas, and it has innumerable nervous connections with every part of their brain. The big olfactory lobes are in direct communication with a thousand other nerves ; odors rouse trains of thought or powerful emotions in their minds just as visible objects do in our own.

Now, in the dog or the horse sight and smell are equally developed ; so that they probably think of most things about equally in terms of each. In ourselves, sight is highly developed, and smell is a mere relic ; so that we think of most things in terms of sight alone, and only rarely, as with a rose or a lily, in terms of both. But in ants, on the contrary, smell is highly developed and sight a mere relic ; so that they probably think of most things as smellable only, and very little as visible, in form or color. Dr. Bastian has shown that bees and butterflies are largely guided by scent ; and though he is certainly wrong in supposing that sight has little to do with leading them to flowers (for if you cut off the bright-colored corolla they will never discover the mutilated blossoms, even when they visit others on the same plant), yet the mere fact that so many flowers are scented is by itself enough to show that perfume has a great deal to do with the matter. In wingless ants, while the eyes have undergone degeneration, this high sense of smell has been continued and further developed, till it has become their principal sense-endowment, and the chief raw material of their intelligence. Their active little brains are almost wholly engaged in correlating and co-ordinating smells with actions. Their olfactory nerves give them nearly all the information they can gain about the external world, and their brains take in this information and work out the proper movements which it indicates. By smell they find their way about and carry on the business of their lives. Just as you and I know the road from Regent's Circus to Pall Mall by visible signs of the street-corners and the Duke of York's Column, so these little ants know the way from the nest to the corpse of the dismembered worm by observing and remembering the smells which they met with on their way. See : I obliterate the track for an inch or two with my stick, and the little creatures go beside themselves with astonishment and dismay. They rush about wildly, inquiring of one another with their antennæ whether this is really Doomsday, and whether the whole course of nature has been suddenly revolutionized. Then, after a short consultation, they determine upon action ; and every ant starts off in a different direction to hunt the lost track, head to the ground, exactly as a pointer hunts the missing trail of a bird or hare. Each ventures an inch or so off, and then runs back to find the rest, for fear he should get isolated altogether. At last, after many failures, one lucky fellow hits upon the well-remembered train of scents, and rushes back, leaving smell-tracks no doubt upon the soil behind him. The message goes quickly round from post to post, each sentry making passes with his antennæ to the next picket, and so sending on the news to the main body in the rear. Within five minutes communications are re-established, and the precious bit of worm-meat continues triumphantly on its way along the recovered path. An ingenious writer would even have us believe that ants possess a scent-language of their own, and emit various odors

from their antennæ which the other ants perceive with theirs, and recognize as distinct in meaning. Be this as it may, you cannot doubt, if you watch them long, that scents and scents alone form the chief means by which they recollect and know one another, or the external objects with which they come in contact. The whole universe is clearly to them a complicated picture made up entirely of infinite interfusing smells.

II.

A WAYSIDE BERRY.

Half-hidden in the luxuriant growth of leaves and flowers that drape the deep side of this green lane, I have just espied a little picture in miniature, a tall wild strawberry-stalk with three full red berries standing out on its graceful branchlets. There are glossy hart's-tongues on the matted bank, and yellow hawkweeds, and bright bunches of red campion; but somehow, amid all that wealth of shape and color, my eye falls and rests instinctively upon the three little ruddy berries, and upon nothing else. I pick the single stalk from the bank and hold it here in my hands. The origin and development of these pretty bits of red pulp is one of the many curious questions upon which modern theories of life have cast such a sudden and unexpected flood of light. What makes the strawberry stalk grow out into this odd and brightly colored lump, bearing its small fruits imbedded on its swollen surface? Clearly the agency of those same small birds who have been mainly instrumental in dressing the haw in its scarlet coat, and clothing the spindle-berries with their twofold covering of crimson doublet and orange cloak.

In common language we speak of each single strawberry as a fruit. But it is in reality a collection of separate fruits, the tiny yellow-brown grains which stud its sides being each of them an individual little nut; while the sweet pulp is, in fact, no part of the true fruit at all, but merely a swollen stalk. There is a white potentilla so like a strawberry blossom that even a botanist must look closely at the plant before he can be sure of its identity. While they are in flower the two heads remain almost indistinguishable; but when the seed begins to set the potentilla develops only a collection of dry fruitlets, seated upon a green receptacle, the bed or soft expansion which hangs on to the "hull" or calyx. Each fruitlet consists of a thin covering, inclosing a solitary seed. You may compare one of them separately to a plum, with its single kernel, only that in the plum the covering is thick and juicy, while in the potentilla and the fruitlets of the strawberry it is thin and dry. An almond comes still nearer to the mark. Now the potentilla shows us, as it were, the primitive form of the strawberry. But in the developed ripe strawberry as we now find it the fruitlets are not crowded upon a green receptacle. After flowering, the strawberry receptacle lengthens and broadens, so as to form a roundish mass of succulent pulp; and as the fruitlets approach maturity this sour green pulp becomes soft, sweet, and red. The little seed-like fruits, which are the important organs, stand out upon its surface like mere specks; while the comparatively unimportant receptacle is all that we usually think of when we talk about strawberries. After our usual Protagorean fashion we regard man as the measure of all things, and pay little heed to any part of the compound fruit-cluster save that which ministers directly to our own tastes.

But why does the strawberry develop this large mass of apparently useless matter? Simply in order the better to insure the dispersion of its small brown fruitlets. Birds are always hunting for seeds and insects along the hedge-rows, and devouring such among them as contain any available foodstuff. In most cases they crush the seeds to pieces with their gizzards, and digest and assimilate their contents. Seeds of this class are generally inclosed in green or brown capsules, which often escape the notice of the birds, and so succeed in perpetuating their species. But there is another class of plants whose members possess hard and indigestible seeds, and

so turn the greedy birds from dangerous enemies into useful allies. Supposing there was by chance, ages ago, one of these primitive ancestral strawberries, whose receptacle was a little more pulpy than usual, and contained a small quantity of sugary matter, such as is often found in various parts of plants; then it might happen to attract the attention of some hungry bird, which, by eating the soft pulp, would help in dispersing the indigestible fruitlets. As these fruitlets sprang up into healthy young plants, they would tend to reproduce the peculiarity in the structure of the receptacle which marked the parent stock, and some of them would probably display it in a more marked degree. These would be sure to get eaten in their turn, and so to become the originators of a still more pronounced strawberry type. As time went on, the largest and sweetest berries would constantly be chosen by the birds, till the whole species began to assume its existing character. The receptacle would become softer and sweeter, and the fruits themselves harder and more indigestible: because, on the one hand, all sour or hard berries would stand a poorer chance of getting dispersed in good situations for their growth, while, on the other hand, all soft-shelled fruitlets would be ground up and digested by the bird, and thus effectually prevented from ever growing into future plants. Just in like manner, many tropical nuts have extravagantly hard shells, as only those survive which can successfully defy the teeth and hands of the clever and persistent monkey.

This accounts for the strawberry being sweet and pulpy, but not for its being red. Here, however, a similar reason comes into play. All ripening fruits and opening flowers have a natural tendency to grow bright red, or purple, or blue, though in many of them the tendency is repressed by the dangers attending brilliant displays of color. This natural habit depends upon the oxidation of their tissues, and is exactly analogous to the assumption of autumn tints by leaves. If a plant, or part of a plant, is injured by such a change of color, though being rendered more conspicuous to its foes, it soon loses the tendency under the influence of natural selection; in other words, those individuals which most display it get killed out, while those which least display it survive and thrive. On the other hand, if conspicuousness is an advantage to the plant, the exact opposite happens, and the tendency becomes developed into a confirmed habit. This is the case with the strawberry, as with many other fruits. The more bright-colored the berry is, the better its chance of getting its fruitlets dispersed. Birds have quick eyes for color, especially for red and white; and therefore almost all edible berries have assumed one or other of these two hues. So long as the fruitlets remain unripe, and would therefore be injured by being eaten, the pulp remains sour, green, and hard; but as soon as they have become fit for dispersion it grows soft, fills with sugary juice, and acquires its ruddy outer flesh. Then the birds see and recognize it as edible, and govern themselves accordingly.

But if this is the genesis of the strawberry, asks somebody, why have not all the potentillas and the whole strawberry tribe also become berries of the same type? Why are there still potentilla fruit-clusters which consist of groups of dry seed-like nuts? Ay, there's the rub. Science cannot answer as yet. After all, these questions are still in their infancy, and we can scarcely yet do more than discover a single stray interpretation here and there. In the present case a botanist can only suggest either that the potentilla finds its own mode of dispersion equally well adapted to its own peculiar circumstances, or else that the lucky accident, the casual combination of circumstances, which produced the first elongation of the receptacle in the strawberry has never happened to befall its more modest kinsfolk. For on such occasional freaks of nature the whole evolution of new varieties entirely depends. A gardener may raise a thousand seedlings, and only one or none among them may present a single new and important feature. So a species may wait for a thousand years,

or forever, before its circumstances happen to produce the first step toward some desirable improvement. One extra petal may be invaluable to a five-rayed flower as effecting some immense saving of pollen in its fertilization; and yet the "sport" which shall give it this sixth ray may never occur, or may be trodden down in the mire and destroyed by a passing cow.

III.

IN SUMMER FIELDS.

Grip and I have come out for a morning stroll among the close-cropped pastures beside the beck, in the very centre of our green little dingle. Here I can sit, as is my wont, on a dry knoll, and watch the birds, beasts, insects, and herbs of the field, while Grip scours the place in every direction, intent, no doubt, upon those more practical objects—mostly rats, I fancy—which possess a congenial interest for the canine intelligence. From my coign of vantage on the knoll I can take care that he inflicts no grievous bodily injury upon the sheep, and that he receives none from the quick-tempered cow with the brass-knobbed horns. For a kind of ancestral feud seems to smoulder forever between Grip and the whole race of kine, breaking out every now and then into open warfare, which calls for my prompt interference, in an attitude of armed but benevolent neutrality, merely for the friendly purpose of keeping the peace.

This ancient feud, I imagine, is really ancestral, and dates many ages farther back in time than Grip's individual experiences. Cows hate dogs instinctively, from their earliest calfhood upward. I used to doubt once upon a time whether the hatred was not of artificial origin and wholly induced by the inveterate human habit of egging on every dog to worry every other animal that comes in its way. But I tried a mild experiment one day by putting a half-grown town-bred puppy into a small inclosure with some hitherto unworried calves, and they all turned to make a common headway against the intruder with the same striking unanimity as the most ancient and experienced cows. Hence I am inclined to suspect that the antipathy does actually result from a vaguely inherited instinct derived from the days when the ancestor of our kine was a wild bull, and the ancestor of our dogs a wolf, on the wide forest-clad plains of Central Europe. When a cow puts up its tail at sight of a dog entering its paddock at the present day, it has probably some dim instinctive consciousness that it stands in the presence of a dangerous hereditary foe; and as the wolves could only seize with safety a single isolated wild bull, so the cows now usually make common cause against the intruding dog, turning their heads in one direction with very unwonted unanimity, till his tail finally disappears under the opposite gate. Such inherited antipathies seem common and natural enough. Every species knows and dreads the ordinary enemies of its race. Mice scamper away from the very smell of a cat. Young chickens run to the shelter of their mother's wings when the shadow of a hawk passes over their heads. Mr. Darwin put a small snake into a paper bag, which he gave to the monkeys at the Zoo; and one monkey after another opened the bag, looked in upon the deadly foe of the quadrumanous kind, and promptly dropped the whole package with every gesture of horror and dismay. Even man himself—though his instincts have all weakened so greatly with the growth of his more plastic intelligence, adapted to a wider and more modifiable set of external circumstances—seems to retain a vague and original terror of the serpentine form.

If we think of parallel cases, it is not curious that animals should thus instinctively recognize their natural enemies. We are not surprised that they recognize their own fellows: and yet they must do so by means of some equally strange automatic and inherited mechanism in their nervous system. One butterfly can tell its mates at once from a thousand other species, though

it may differ from some of them only by a single spot or line, which would escape the notice of all but the most attentive observers. Must we not conclude that there are elements in the butterfly's feeble brain exactly answering to the blank picture of its specific type? So, too, must we not suppose that in every race of animals there arises a perceptive structure specially adopted to the recognition of its own kind? Babies notice human faces long before they notice any other living thing. In like manner we know that most creatures can judge instinctively of their proper food. One young bird just fledged naturally pecks at red berries; another exhibits an untaught desire to chase down grasshoppers; a third, which happens to be born an owl, turns at once to the congenial pursuit of small sparrows, mice, and frogs. Each species seems to have certain faculties so arranged that the sight of certain external objects, frequently connected with food in their ancestral experience, immediately arouses in them the appropriate actions for its capture. Mr. Douglas Spalding found that newly-hatched chickens darted rapidly and accurately at flies on the wing. When we recollect that even so late an acquisition as articulate speech in human beings has its special physical seat in the brain, it is not astonishing that complicated mechanisms should have arisen among animals for the due perception of mates, food, and foes respectively. Thus, doubtless, the serpent form has imprinted itself indelibly on the senses of monkeys, and the wolf or dog form on those of cows: so that even with a young ape or calf the sight of these their ancestral enemies at once calls up uneasy or terrified feelings in their half-developed minds. Our own infants in arms have no personal experience of the real meaning to be attached to angry tones, yet they shrink from the sound of a gruff voice even before they have learned to distinguish their nurse's face.

When Grip gets among the sheep, their hereditary traits come out in a very different manner. They are by nature and descent timid mountain animals, and they have never been accustomed to face a foe, as cows and buffaloes are wont to do, especially when in a herd together. You cannot see many traces of the original mountain life among sheep, and yet there are still a few remaining to mark their real pedigree. Mr. Herbert Spencer has noticed the fondness of lambs for frisking on a hillock, however small; and when I come to my little knoll here, I generally find it occupied by a couple, who rush away on my approach, but take their stand instead on the merest ant-hill which they can find in the field. I once knew three young goats, kids of a mountain breed, and the only elevated object in the paddock where they were kept was a single old elm stump. For the possession of this stump the goats fought incessantly; and the victor would proudly perch himself on the top, with all four legs inclined inward (for the whole diameter of the tree was but some fifteen inches), maintaining himself in his place with the greatest difficulty, and butting at his two brothers until at last he lost his balance and fell. This one old stump was the sole representative in their limited experience of the rocky pinnacle upon which their forefathers kept watch like sentinels; and their instinctive yearnings prompted them to perch themselves upon the only available memento of their native haunts. Thus, too, but in a dimmer and vaguer way, the sheep, especially during his younger days, loves to revert, so far as his small opportunities permit him, to the unconsciously remembered habits of his race. But in mountain countries, every one must have noticed how the sheep at once becomes a different being. On the Welsh hills he casts away all the dull and heavy serenity of his brethren on the South Downs, and displays once more the freedom, and even the comparative boldness, of a mountain breed. A Merionethshire ewe thinks nothing of running up one side of a low-roofed barn and down the other, or of clearing a stone wall which a Leicestershire farmer would consider extravagantly high.

Another mountain trait in the stereotyped character of sheep is their well-known sequaciousness. When Grip runs after them they all run away together: if one goes through a certain gap in the hedge, every other follows; and if the leader jumps the beck at a certain spot, every lamb in the flock jumps in the self-same place. It is said that if you hold a stick for the first sheep to leap over, and then withdraw it, all the succeeding sheep will leap with mathematical accuracy at the corresponding point; and this habit is usually held up to ridicule as proving the utter stupidity of the whole race. It really proves nothing but the goodness of their ancestral instincts. For mountain animals, accustomed to follow a leader, that leader being the bravest and strongest ram of the flock, must necessarily follow him with the most implicit obedience. He alone can see what obstacles come in the way; and each of the succeeding train must watch and imitate the actions of their predecessors. Otherwise, if the flock happens to come to a chasm, running as they often must with some speed, any individual which stopped to look and decide for itself before leaping would inevitably be pushed over the edge by those behind it, and so would lose all chance of handing down its cautious and sceptical spirit to any possible descendants. On the other hand, those uninquiring and blindly obedient animals which simply did as they saw others do would both survive themselves and become the parents of future and similar generations. Thus there would be handed down from dam to lamb a general tendency to sequaciousness—a follow-my-leader spirit, which was really the best safeguard for the race against the evils of insubordination, still so fatal to Alpine climbers. And now that our sheep have settled down to a tame and monotonous existence on the downs of Sussex or the levels of the Midlands, the old instinct clings to them still, and speaks out plainly for their mountain origin. There are few things in nature more interesting to notice than these constant survivals of instinctive habits in altered circumstances. They are to the mental life what rudimentary organs are to the bodily structure: they remind us of an older order of things, just as the abortive legs of the blind-worm show us that he was once a lizard, and the hidden shell of the slug that he was once a snail.

IV.

A SPRIG OF WATER CROWFOOT.

The little streamlet whose tiny ranges and stickles form the middle thread of this green combe in the Dorset downs is just at present richly clad with varied foliage. Tall spikes of the yellow flag rise above the slow-flowing pools, while purple loose-strife overhangs the bank, and bunches of the arrowhead stand high out of their watery home, just unfolding their pretty waxen white flowers to the air. In the rapids, on the other hand, I find the curious water crowfoot, a spray of which I have this moment pulled out of the stream and am now holding in my hand as I sit on the little stone bridge, with my legs dangling over the pool below, known to me as the undoubted residence of a pair of trout. It is a queer plant, this crowfoot, with its two distinct types of leaves, much cleft below and broad above; and I often wonder why so strange a phenomenon has attracted such very scant attention. But then we knew so little of life in any form till the day before yesterday that perhaps it is not surprising we should still have left so many odd problems quite untouched.

This problem of the shape of leaves certainly seems to me a most important one; and yet it has hardly been even recognized by our scientific pastors and masters. At best, Mr. Herbert Spencer devotes to it a passing short chapter, or Mr. Darwin a stray sentence. The practice of classifying plants mainly by means of their flowers has given the flower a wholly factitious and overwrought importance. Besides, flowers are so pretty, and we cultivate them so largely, with little regard to the leaves,

that they have come to usurp almost the entire interest of botanists and horticulturists alike. Darwinism itself has only heightened this exclusive interest by calling attention to the reciprocal relations which exist between the honey-bearing blossom and the fertilizing insect, the bright-colored petals and the myriad facets of the butterfly's eye. Yet the leaf is after all the real plant, and the flower is but a sort of afterthought, an embryo colony set apart for the propagation of like plants in future. Each leaf is in truth a separate individual organism, united with many others into a compound community, but possessing in full its own mouths and digestive organs, and carrying on its own life to a great extent independently of the rest. It may die without detriment to them ; it may be lopped off with a few others as a cutting, and it continues its life-cycle quite unconcerned. An oak tree in full foliage is a magnificent group of such separate individuals— a whole nation in miniature: it may be compared to a branched coral polypedom covered with a thousand little insect workers, while each leaf answers rather to the separate polypes themselves. The leaves are even capable of producing new individuals by what they contribute to the buds on every branch ; and the seeds which the tree as a whole produces are to be looked upon rather as the founders of fresh colonies, like the swarms of bees, than as fresh individuals alone. Every plant community, in short, both adds new members to its own commonwealth, and sends off totally distinct germs to form new commonwealths elsewhere. Thus the leaf is, in truth, the central reality of the whole plant, while the flower exists only for the sake of sending out a shipload of young emigrants every now and then to try their fortunes in some unknown soil.

The whole life-business of a leaf is, of course, to eat and grow, just as these same functions form the whole life-business of a caterpillar or a tadpole. But the way a plant eats, we all know, is by taking carbon and hydrogen from air and water under the influence of sunlight, and building them up into appropriate compounds in its own body. Certain little green worms or convoluta have the same habit, and live for the most part cheaply off sunlight, making starch out of carbonic acid and water by means of their inclosed chlorophyl, exactly as if they were leaves. Now, as this is what a leaf has to do, its form will almost entirely depend upon the way it is affected by sunlight and the elements around it—except, indeed, in so far as it may be called upon to perform other functions, such as those of defence or defiance. This crowfoot is a good example of the results produced by such agents. Its lower leaves, which grow under water, are minutely subdivided into little branching lance-like segments ; while its upper ones, which raise their heads above the surface, are broad and united, like the common crowfoot type. How am I to account for these peculiarities ? I fancy somehow thus :

Plants which live habitually under water almost always have thin, long, pointed leaves, often thread-like or mere waving filaments. The reason for this is plain enough. Gases are not very abundant in water, as it only holds in solution a limited quantity of oxygen and carbonic acid. Both of these the plant needs, though in varying quantities : the carbon to build up its starch, and the oxygen to use up in its growth. Accordingly, broad and large leaves would starve under water : there is not material enough diffused through it for them to make a living from. But small, long, waving leaves which can move up and down in the stream would manage to catch almost every passing particle of gaseous matter, and to utilize it under the influence of sunlight. Hence all plants which live in fresh water, and especially all plants of higher rank, have necessarily acquired such a type of leaf. It is the only form in which growth can possibly take place under their circumstances. Of course, however, the particular pattern of leaf depends largely upon the ancestral form. Thus this crowfoot, even in its submerged leaves, preserves the general

arrangement of ribs and leaflets common to the whole buttercup tribe. For the crowfoot family is a large and eminently adaptable race. Some of them are larkspurs and similar queerly-shaped blossoms ; others are columbines which hang their complicated bells on dry and rocky hillsides ; but the larger part are buttercups or marsh marigolds which have simple cup-shaped flowers, and mostly frequent low and marshy ground. One of these typical crowfoots under stress of circumstances—inundation, or the like—took once upon a time to living pretty permanently in the water. As its native meadows grew deeper and deeper in flood it managed from year to year to assume a more nautical life. So, while its leaf necessarily remained in general structure a true crowfoot leaf, it was naturally compelled to split itself up into thinner and narrower segments, each of which grew out in the direction where it could find most stray carbon atoms, and most sunlight, without interference from its neighbors. This, I take it, was the origin of the much-divided lower leaves.

But a crowfoot could never live permanently under water. Seaweeds and their like, which propagate by a kind of spores, may remain below the surface forever ; but flowering plants for the most part must come up to the open air to blossom. The sea-weeds are in the same position as fish, originally developed in the water and wholly adapted to it, whereas flowering plants are rather analogous to seals and whales, air-breathing creatures, whose ancestors lived on land, and who can themselves manage an aquatic existence only by frequent visits to the surface. So some flowering water-plants actually detach their male blossoms altogether, and let them float loose on the top of the water ; while they send up their female flowers by means of a spiral coil, and draw them down again as soon as the wind or the fertilizing insects have carried the pollen to its proper receptacle, so as to ripen their seeds at leisure beneath the pond. Similarly, you may see the arrowhead and the water-lilies sending up their buds to open freely in the air, or loll at ease upon the surface of the stream. Thus the crowfoot, too, cannot blossom to any purpose below the water ; and as such among its ancestors as at first tried to do so must of course have failed in producing any seed, they and their kind have died out forever ; while only those lucky individuals whose chance lot it was to grow a little taller and weedier than the rest, and so overtop the stream, have handed down their race to our own time.

But as soon as the crowfoot finds itself above the level of the river, all the causes which made its leaf like those of other aquatic plants have ceased to operate. The new leaves which sprout in the air meet with abundance of carbon and sunlight on every side ; and we know that plants grow fast just in proportion to the supply of carbon. They have pushed their way into an unoccupied field, and they may thrive apace without let or hindrance So, instead of splitting up into little lance-like leaflets, they loll on the surface, and spread out broader and fuller, like the rest of their race. The leaf becomes at once a broad type of crowfoot leaf. Even the ends of the submerged leaves, when any fall of the water in time of drought raises them above the level, have a tendency (as I have often noticed) to grow broader and fatter, with increased facilities for food ; but when the whole leaf rises from the first to the top the inherited family instinct finds full play for its genius, and the blades fill out as naturally as well-bred pigs. The two types of leaf remind one much of gills and lungs respectively.

But above water, as below it, the crowfoot remains in principle a crowfoot still. The traditions of its race, acquired in damp marshy meadows, not actually under water, cling to it yet in spite of every change. Born river and pond plants which rise to the surface, like the water-lily or the duckweed, have broad floating leaves that contrast strongly with the waving filaments of wholly submerged species. They can find plenty of food everywhere, and as the sunlight falls flat upon them, they may as well spread out

flat to catch the sunlight. No other elbowing plants overtop them and appropriate the rays, so compelling them to run up a useless waste of stem in order to pocket their fair share of the golden flood. Moreover, they thus save the needless expense of a stout leaf-stalk, as the water supports their lolling leaves and blossoms ; while the broad shade which they cast on the bottom below prevents the undue competition of other species. But the crowfoot, being by descent a kind of buttercup, has taken to the water for a few hundred generations only, while the water-lily's ancestors have been to the manner born for millions of years ; and therefore it happens that the crowfoot is at heart but a meadow buttercup still. One glance at its simple little flower will show you that in a moment.

V.

SLUGS AND SNAILS.

Hoeing among the flower-beds on my lawn this morning—for I am a bit of a gardener in my way—I have had the ill-luck to maim a poor yellow slug, who had hidden himself among the encroaching grass on the edge of my little parterre of sky-blue lobelias. This unavoidable wounding and hacking of worms and insects, despite all one's care, is no small drawback to the pleasures of gardening *in propriâ personâ.* Vivisection for genuine scientific purposes in responsible hands, one can understand and tolerate, even though lacking the heart for it one's self ; but the useless and causeless vivisection which cannot be prevented in every ordinary piece of farm-work seems a gratuitous blot upon the face of beneficent nature. My only consolation lies in the half-formed belief that feeling among these lower creatures is indefinite, and that pain appears to affect them far less acutely than it affects warm-blooded animals. Their nerves are so rudely distributed in loose knots all over the body, instead of being closely bound together into a single central system as with ourselves, that they can scarcely possess a consciousness of pain at all analogous to our own. A wasp whose head has been severed from its body and stuck upon a pin, will still greedily suck up honey with its throatless mouth ; while an Italian mantis, similarly treated, will calmly continue to hunt and dart at midges with its decapitated trunk and limbs, quite forgetful of the fact that it has got no mandibles left to eat them with. These peculiarities lead one to hope that insects may feel pain less than we fear. Yet I dare scarcely utter the hope, lest it should lead any thoughtless hearer to act upon the very questionable belief, as they say even the amiable enthusiasts of Port Royal acted upon the doctrine that animals were mere unconscious automata, by pushing their theory to the too practical length of active cruelty. Let us at least give the slugs and beetles the benefit of the doubt. People often say that science makes men unfeeling : for my own part, I fancy it makes them only the more humane, since they are the better able dimly to figure to themselves the pleasures and pains of humbler beings as they really are. The man of science perhaps realizes more vividly than all other men the inner life and vague rights even of crawling worms and ugly earwigs.

I will take up this poor slug whose mishap has set me preaching, and put him out of his misery at once, if misery it be. My hoe has cut through the soft flesh of the mantle and hit against the little embedded shell. Very few people know that a slug has a shell, but it has, though quite hidden from view ; at least, in this yellow kind—for there are other sorts which have got rid of it altogether. I am not sure that I have wounded the poor thing very seriously ; for the shell protects the heart and vital organs, and the hoe has glanced off on striking it, so that the mantle alone is injured, and that by no means irrecoverably. Snail flesh heals fast, and on the whole I shall be justified, I think, in letting him go. But it is a very curious thing that this slug should have a shell at all ! Of course it is by descent a snail, and, in-

deed, there are very few differences between the two races except in the presence or absence of a house. You may trace a curiously complete set of gradations between the perfect snail and the perfect slug in this respect ; for all the intermediate forms still survive with only an almost imperceptible gap between each species and the next. Some kinds, like the common brown garden snail, have comparatively small bodies and big shells, so that they can retire comfortably within them when attacked ; and if they only had a lid or door to their houses they could shut themselves up hermetically, as periwinkles and similar mollusks actually do. Other kinds, like the pretty golden amber-snails which frequent marshy places, have a body much too big for its house, so that they cannot possibly retire within their shells completely. Then come a number of intermediate species, each with progressively smaller and thinner shells, till at length we reach the testacella, which has only a sort of limpet-shaped shield on his tail, so that he is generally recognized as being the first of the slugs rather than the last of the snails. You will not find a testacella unless you particularly look for him, for he seldom comes above ground, being a most bloodthirsty subterraneous carnivore who follows the burrows of earthworms as savagely as a ferret tracks those of rabbits ; but in all the southern and western counties you may light upon stray specimens if you search carefully in damp places under fallen leaves. Even in testacellæ, however, the small shell is still external. In this yellow slug here, on the contrary, it does not show itself at all, but is buried under the closely wrinkled skin of the glossy mantle. It has become a mere saucer, with no more symmetry or regularity than an oyster-shell. Among the various kinds of slugs, you may watch this relic or rudiment gradually dwindling further and further towards annihilation ; till finally, in the great fat black slugs which appear so plentifully on the roads after summer showers, it is represented only by a few rough calcareous grains, scattered up and down through the mantle ; and sometimes even these are wanting. The organs which used to secrete the shell in their remote ancestors have either ceased to work altogether or are reduced to performing a useless office by mere organic routine.

The reason why some mollusks have thus lost their shells is clear enough. Shells are of two kinds, calcareous and horny. Both of them require more or less lime or other mineral matters, though in varying proportions. Now, the snails which thrive best on the bare chalk downs behind my little combe belong to that pretty banded black-and-white sort which everybody must have noticed feeding in abundance on all chalk soils. Indeed, Sussex farmers will tell you that South Down mutton owes its excellence to these fat little mollusks, not to the scanty herbage of their thin pasture-lands. The pretty banded shells in question are almost wholly composed of lime, which the snails can, of course, obtain in any required quantity from the chalk. In most limestone districts you will similarly find that snails with calcareous shells predominate. But if you go into a granite or sandstone tract you will see that horny shells have it all their own way. Now, some snails with such houses took to living in very damp and marshy places, which they were naturally apt to do—as indeed the land-snails in a body are merely pond-snails which have taken to crawling up the leaves of marsh-plants, and have thus gradually acclimatized themselves to a terrestrial existence. We can trace a perfectly regular series from the most aquatic to the most land-loving species, just as I have tried to trace a regular series from the shell-bearing snails to the shell-less slugs. Well, when the earliest common ancestor of both these last-named races first took to living above water, he possessed a horny shell (like that of the amber-snail), which his progenitors used to manufacture from the mineral matters dissolved in their native streams. Some of the younger branches descended from this primeval land-snail took to living on

very dry land, and when they reached chalky districts manufactured their shells, on an easy and improved principle, almost entirely out of lime. But others took to living in moist and boggy places, where mineral matter was rare, and where the soil consisted for the most part of decaying vegetable mould. Here they could get little or no lime, and so their shells grew smaller and smaller, in proportion as their habits became more decidedly terrestrial. But to the last, as long as any shell at all remained, it generally covered their hearts and other important organs ; because it would there act as a special protection, even after it had ceased to be of any use for the defence of the animal's body as a whole. Exactly in the same way men specially protected their heads and breasts with helmets and cuirasses, before armor was used for the whole body, because these were the places where a wound would be most dangerous ; and they continued to cover these vulnerable spots in the same manner even when the use of armor had been generally abandoned. My poor mutilated slug, who is just now crawling off contentedly enough towards the hedge, would have been cut in two outright by my hoe had it not been for that solid calcareous plate of his, which saved his life as surely as any coat of mail.

How does it come, though, that slugs and snails now live together in the selfsame districts ? Why, because they each live in their own way. Slugs belong by origin to very damp and marshy spots ; but in the fierce competition of modern life they spread themselves over comparatively dry places, provided there is long grass to hide in, or stones under which to creep, or juicy herbs like lettuce, among whose leaves are nice moist nooks wherein to lurk during the heat of the day. Moreover, some kinds of slugs are quite as well protected from birds (such as ducks) by their nauseous taste as snails are by their shells. Thus it happens that at present both races may be discovered in many hedges and thickets side by side. but the real home of each is quite different. The truest and most snail-like snails are found in greatest abundance upon high chalk-downs, heathy limestone hills, and other comparatively dry places ; while the truest and most slug-like slugs are found in greatest abundance among low water-logged meadows, or under the damp fallen leaves of moist copses. The intermediate kinds inhabit the intermediate places. Yet to the last even the most thorough-going snails retain a final trace of their original water-haunting life, in their universal habit of seeking out the coolest and moistest spots of their respective habitats. The soft-fleshed mollusks are all by nature aquatic animals, and nothing can induce them wholly to forget the old tradition of their marine or fresh-water existence.

VI.

A STUDY OF BONES.

On the top of this bleak chalk down, where I am wandering on a dull afternoon, I light upon the blanched skeleton of a crow, which I need not fear to handle, as its bones have been first picked clean by carrion birds, and then finally purified by hungry ants, time, and stormy weather. I pick a piece of it up in my hands, and find that I have got hold of its clumped tail-bone. A strange fragment truly, with a strange history, which I may well spell out as I sit to rest a minute upon the neighboring stile. For this dry tail-bone consists, as I can see at a glance, of several separate vertebræ, all firmly welded together into a single piece. They must once upon a time have been real disconnected jointed vertebræ, like those of the dog's or lizard's tail ; and the way in which they have become fixed fast into a solid mass sheds a world of light upon the true nature and origin of birds, as well as upon many analogous cases elsewhere.

When I say that these bones were once separate, I am indulging in no mere hypothetical Darwinian speculation. I refer, not to the race, but to the particular crow in person. These very pieces themselves, in their embry-

onic condition, were as distinct as the individual bones of the bird's neck or of our own spines. If you were to examine the chick in the egg you would find them quite divided. But as the young crow grows more and more into the typical bird-pattern, this lizard-like peculiarity fades away, and the separate pieces unite by "anastomosis" into a single "coccygean bone," as the osteologists call it. In all our modern birds, as in this crow, the vertebræ composing the tail-bone are few in number, and are soldered together immovably in the adult form. It was not always so, however, with ancestral birds. The earliest known member of the class—the famous fossil bird of the Solenhofen lithographic stone—retained throughout its whole life a long flexible tail, composed of twenty unwelded vertebræ, each of which bore a single pair of quill-feathers, the predecessors of our modern pigeon's train. There are many other marked reptilian peculiarities in this primitive oolitic bird; and it apparently possessed true teeth in its jaws, as its later cretaceous kinsmen discovered by Professor Marsh undoubtedly did. When we compare side by side those real flying dragons, the Pterodactyls, together with the very bird-like Deinosaurians, on the one hand, and these early toothed and lizard-tailed birds on the other, we can have no reasonable doubt in deciding that our own sparrows and swallows are the remote feathered descendants of an original reptilian or half-reptilian ancestor.

Why modern birds have lost their long flexible tails it is not difficult to see. The tail descends to all higher vertebrates as an heir-loom from the fishes, the amphibia, and their other aquatic predecessors. With these it is a necessary organ of locomotion in swimming, and it remains almost equally useful to the lithe and gliding lizard on land. Indeed, the snake is but a lizard who has substituted this wriggling motion for the use of legs altogether; and we can trace a gradual succession from the four-legged true lizards, through snake-like forms with two legs and wholly rudimentary legs, to the absolutely limbless serpents themselves. But to flying birds, on the contrary, a long bony tail is only an inconvenience. All that they need is a little muscular knob for the support of the tail-feathers, which they employ as a rudder in guiding their flight upward or downward, to right or left. The elongated waving tail of the Solenhofen bird, with its single pair of quills, must have been a comparatively ineffectual and clumsy piece of mechanism for steering an aërial creature through its novel domain. Accordingly, the bones soon grew fewer in number and shorter in length, while the feathers simultaneously arranged themselves side by side upon the terminal hump. As early as the time when our chalk was deposited, the bird's tail had become what it is at the present day—a single united bone, consisting of a few scarcely distinguishable crowded rings. This is the form it assumes in the toothed fossil birds of Western America. But, as if to preserve the memory of their reptilian origin, birds in their embryo stage still go on producing separate caudal vertebræ, only to unite them together at a later point of their development into the typical coccygean bone.

Much the same sort of process has taken place in the higher apes, and, as Mr. Darwin would assure us, in man himself. There the long prehensile tail of the monkeys has grown gradually shorter, and, being at last coiled up under the haunches, has finally degenerated into an insignificant and wholly imbedded terminal joint. But, indeed, we can find traces of a similar adaptation to circumstances everywhere. Take, for instance, the common English amphibians. The newt passes all its life in the water, and therefore always retains its serviceable tail as a swimming organ. The frog in its tadpole state is also aquatic, and it swims wholly by means of its broad and flat rudder-like appendage. But as its legs bud out, and it begins to fit itself for a terrestrial existence, the tail undergoes a rapid atrophy, and finally fades away altogether. To a hopping frog on land, such a long train would be a useless

drag, while in the water its webbed feet and muscular legs make a satisfactory substitute for the lost organ. Last of all, the tree-frog, leading a specially terrestrial life, has no tadpole at all, but emerges from the egg in the full frog-like shape. As he never lives in the water, he never feels the need of a tail.

The edible crab and lobster show us an exactly parallel case among crustaceans. Everybody has noticed that a crab's body is practically identical with a lobster's, only that in the crab the body-segments are broad and compact, while the tail, so conspicuous in its kinsman, is here relatively small and tucked away unobtrusively behind the legs. This difference in construction depends entirely upon the habits and manners of the two races. The lobster lives among rocks and ledges ; he uses his small legs but little for locomotion, but he springs surprisingly fast and far through the water by a single effort of his powerful muscular tail. As to his big fore-claws, those, we all know, are organs of prehension and weapons of offence, not pieces of locomotive mechanism. Hence the edible and muscular part of a lobster is chiefly to be found in the claws and tail, the latter having naturally the firmest and strongest flesh. The crab, on the other hand, lives on the sandy bottom, and walks about on its lesser legs, instead of swimming or darting through the water by blows of its tail, like the lobster or the still more active prawn and shrimp. Hence the crab's tail has dwindled away to a mere useless historical relic, while the most important muscles in its body are those seated in the network of shell just above its locomotive legs. In this case, again, it is clear that the appendage has disappeared because the owner had no further use for it. Indeed, if one looks through all nature, one will find the philosophy of tails eminently simple and utilitarian Those animals that need them evolve them ; those animals that do not need them never develop them ; and those animals that have once had them, but no longer use them for practical purposes, retain a mere shrivelled rudiment as a lingering reminiscence of their original habits.

VII.

BLUE MUD.

After last night's rain, the cliffs that bound the bay have come out in all their most brilliant colors ; so this morning I am turning my steps seaward, and wandering along the great ridge of pebbles which here breaks the force of the Channel waves as they beat against the long line of the Dorset downs. Our cliffs just at this point are composed of blue lias beneath, with a capping of yellow sandstone on their summits, above which in a few places the layer of chalk that once topped the whole country-side has still resisted the slow wear and tear of unnumbered centuries. These three elements give a variety to the bold and broken bluffs which is rare along the monotonous southern escarpment of the English coast. After rain, especially, the changes of color on their sides are often quite startling in their vividness and intensity. To-day, for example, the yellow sandstone is tinged in parts with a deep russet red, contrasting admirably with the bright green of the fields above and the sombre steel-blue of the lias belt below. Besides, we have had so many landslips along this bit of shore, that the various layers of rock have in more than one place got mixed up with one another into inextricable confusion. The little town nestling in the hollow behind me has long been famous as the headquarters of early geologists ; and not a small proportion of the people earn their livelihood to the present day by "goin' a fossiling." Every child about the place recognizes ammonites as "snake-stones ;" while even the rarer vertebræ of extinct saurians have acquired a local designation as "verterberries." So, whether in search of science or the picturesque, I often clamber down in this direction for my daily stroll, particularly when, as is the case to-day, the rain has had time to trickle through the yellow rock, and the sun then shines full against its face, to

light it up with a rich flood of golden splendor.

The base of the cliffs consists entirely of a very soft and plastic blue lias mud. This mud contains large numbers of fossils, chiefly chambered shells, but mixed with not a few relics of the great swimming and flying lizards that swarmed among the shallow flats or low islands of the lias sea. When the blue mud was slowly accumulating in the hollows of the ancient bottom, these huge saurians formed practically the highest race of animals then existing upon earth. There were, it is true, a few primeval kangaroo-mice and wombats among the rank brushwood of the mainland; and there may even have been a species or two of reptilian birds, with murderous-looking teeth and long lizard-like tails—descendants of those problematical creatures which printed their footmarks on the American trias, and ancestors of the later toothed bird whose tail-feathers have been naturally lithographed for us on the Solenhofen slate. But in spite of such rare precursors of higher modern types, the saurian was in fact the real lord of earth in the lias ocean.

For him did his high sun flame, and his river billowing ran,
And he felt himself in his pride to be nature's crowing race.

We have adopted an easy and slovenly way of dividing all rocks into primary, secondary, and tertiary, which veils from us the real chronological relations of evolving life in the different periods. The lias is ranked by geologists among the earliest secondary formations; but if we were to distribute all the sedimentary rocks into ten great epochs, each representing about equal duration in time, the lias would really fall in the tenth and latest of all. So very misleading to the ordinary mind is our accepted geological nomenclature. Nay, even commonplace geologists themselves often overlook the real implications of many facts and figures which they have learned to quote glibly enough in a certain off-hand way. Let me just briefly reconstruct the chief features of this scarcely recognized world's chronology as I sit on this piece of fallen chalk at the foot of the mouldering cliff, where the stream from the meadow above brought down the newest landslip during the hard frosts of last December. First of all, there is the vast lapse of time represented by the Laurentian rocks of Canada. These Laurentian rocks, the oldest in the world, are at least 30,000 feet in thickness, and it must be allowed that it takes a reasonable number of years to accumulate such a mass of solid limestone or clay as that at the bottom of even the widest primeval ocean. In these rocks there are no fossils, except a single very doubtful member of the very lowest animal type. But there are indirect traces of life in the shape of limestone probably derived from shells, and of black lead probably derived from plants. All these early deposits have been terribly twisted and contorted by subsequent convulsions of the earth, and most of them have been melted down by volcanic action; so that we can tell very little about their original state. Thus the history of life opens for us, like most other histories, with a period of uncertainty: its origin is lost in the distant vistas of time. Still, we know that there *was* such an early period; and from the thickness of the rocks which represent it we may conjecture that it spread over three out of the ten great æons into which I have roughly divided geological time. Next comes the period known as the Cambrian, and to it we may similarly assign about two and a half æons on like grounds. The Cambrian epoch begins with a fair sprinkling of the lower animals and plants, presumably developed during the preceding age; but it shows no remains of fish or any other vertebrates. To the Silurian, Devonian, and Carboniferous periods we may roughly allow an æon and a fraction each; while to the whole group of secondary and tertiary strata, comprising almost all the best-known English formations—red marl, lias, oolite, greensand, chalk, eocene, miocene, pliocene, and drift—we can only give a single æon to be divided between them. Such facts will

sufficiently suggest how comparatively modern are all these rocks when viewed by the light of an absolute chronology. Now, the first fishes do not occur till the Silurian—that is to say, in or about the seventh æon after the beginning of geological time. The first mammals are found in the trias, at the beginning of the tenth æon. And the first known bird only makes its appearance in the oolite, about half way through that latest period. This will show that there was plenty of time for their development in the earlier ages. True, we must reckon the interval between ourselves and the date of this blue mud at many millions of years; but then we must reckon the interval between the lias and the earliest Cambrian strata at some six times as much, and between the lias and the lowest Laurentian beds at nearly ten times as much. Just the same sort of lessening perspective exists in geology as in ordinary history. Most people look upon the age before the Norman conquest as a mere brief episode of the English annals; yet six whole centuries elapsed between the landing of the real or mythical Hengst at Ebbsfleet and the landing of William the Conqueror at Hastings; while under eight centuries elapsed between the time of William the Conqueror and the accession of Queen Victoria. But, just as most English histories give far more space to the three centuries since Elizabeth than to the eleven centuries which preceded them, so most books on geology give far more space to the single æon (embracing the secondary and tertiary periods) which comes nearest our own time, than to the nine æons which spread from the Laurentian to the Carboniferous epoch. In the earliest period, records either geological or historical are wholly wanting; in the later periods they become both more numerous and more varied in proportion as they approach nearer and nearer to our own time.

So, too, in the days when Mr. Darwin first took away the breath of scientific Europe by his startling theories, it used confidently to be said that geology had shown us no intermediate form between species and species. Even at the time when this assertion was originally made it was quite untenable. All early geological forms, of whatever race, belong to what we foolishly call "generalized" types: that is to say, they present a mixture of features now found separately in several different animals. In other words, they represent early ancestors of all the modern forms, with peculiarities intermediate between those of their more highly differentiated descendants; and hence we ought to call them "unspecialized" rather than "generalized" types. For example, the earliest ancestral horse is partly a horse and partly a tapir: we may regard him as a *tertium quid*, a middle term, from which the horse has varied in one direction and the tapir in another, each of them exaggerating certain special peculiarities of the common ancestor and losing others, in accordance with the circumstances in which they have been placed. Science is now perpetually discovering intermediate forms, many of which compose an unbroken series between the unspecialized ancestral type and the familiar modern creatures. Thus, in this very case of the horse, Professor Marsh has unearthed a long line of fossil animals which lead in direct descent from the extremely unhorse-like eocene type to the developed Arab of our own times. Similarly with birds, Professor Huxley has shown that there is hardly any gap between the very bird-like lizards of the lias and the very lizard-like birds of the oolite. Such links, discovered afresh every day, are perpetual denials to the old parrot-like cry of "No geological evidence for evolution."

VIII.

CUCKOO-PINT.

In the bank which supports the hedge, beside this little hanger on the flank of Black Down, the glossy arrow-headed leaves of the common arum form at this moment beautiful masses of vivid green foliage. "Cuckoo-pint" is the pretty poetical old English name for the plant; but village children know

it better by the equally quaint and fanciful title of "lords and ladies." The arum is not now in flower: it blossomed much earlier in the season, and its queer clustered fruits are just at present swelling out into rather shapeless little light-green bulbs, preparatory to assuming the bright coral-red hue which makes them so conspicuous among the hedgerows during the autumn months. A cut-and-dry technical botanist would therefore have little to say to it in its present stage, because he cares only for the flowers and seeds which help him in his dreary classifications, and give him so splendid an opportunity for displaying the treasures of his Latinized terminology. But to me the plant itself is the central point of interest, not the names (mostly in bad Greek) by which this or that local orchid-hunter has endeavored to earn immortality.

This arum, for example, grows first from a small hard seed with a single lobe or seed-leaf. In the seed there is a little store of starch and albumen laid up by the mother-plant, on which the young arum feeds, just as truly as the growing chick feeds on the white which surrounds its native yolk, or as you and I feed on the similar starches and albumens laid by for the use of the young plant in the grain of wheat, or for the young fowl in the egg. Full-grown plants live by taking in food-stuffs from the air under the influence of sunlight; but a young seedling can no more feed itself than a human baby can; and so food is stored up for it beforehand by the parent stock. As the kernel swells with heat and moisture, its starches and albumens get oxidized and produce the motions and rearrangements of particles that result in the growth of a new plant. First a little head rises toward the sunlight and a little root pushes downward toward the moist soil beneath. The business of the root is to collect water for the circulating medium—the sap or blood of the plant—as well as a few mineral matters required for its stem and cells; but the business of the head is to spread out into leaves, which are the real mouths and stomachs of the compound organism. For we must never forget that all plants mainly grow, not, as most people suppose, from the earth, but from the air. They are for the most part mere masses of carbon-compounds, and the carbon in them comes from the carbonic acid diffused through the atmosphere around, and is separated by the sunlight acting in the leaves. There it mixes with small quantities of hydrogen and nitrogen brought by the roots from soil and water; and the starches or other bodies thus formed are then conveyed by the sap to the places where they will be required in the economy of the plant system. That is the all-important fact in vegetable physiology, just as the digestion and assimilation of food and the circulation of the blood are in our own bodies.

The arum, like the grain of wheat, has only a single seed-leaf; whereas the pea, as we all know, has two. This is the most fundamental difference among flowering plants, as it points back to an early and deep-seated mode of growth, about which they must have split off from one another millions of years ago. All the one-lobed plants grow with stems like grasses or bamboos, formed by single leaves inclosing another; all the double lobed plants grow with stems like an oak, formed of concentric layers from within outward. As soon as the arum, with its sprouting head, has raised its first leaves far enough above the ground to reach the sunlight, it begins to form fresh starches and new leaves for itself, and ceases to be dependent upon the store laid up in its buried lobe. Most seeds accordingly contain just enough material to support the young seedling till it is in a position to shift for itself; and this, of course, varies greatly with the habits and manners of the particular species. Some plants, too, such as the potato, find their seeds insufficient to keep up the race by themselves, and so lay by abundant starches in underground branches or tubers, for the use of new shoots; and these rich starch receptacles we ourselves generally utilize as food-stuffs, to the manifest detriment

of the young potato-plants, for whose benefit they were originally intended. Well, the arum has no such valuable reserve as that; it is early cast upon its own resources, and so it shifts for itself with resolution. Its big, glossy leaves grow apace, and soon fill out, not only with green chlorophyl, but also with a sharp and pungent essence which makes them burn the mouth like cayenne pepper. This acrid juice has been acquired by the plant as a defence against its enemies. Some early ancestor of the arums must have been liable to constant attacks from rabbits, goats, or other herbivorous animals, and it has adopted this means of repelling their advances. In other words, those arums which were most palatable to the rabbits got eaten up and destroyed, while those which were nastiest survived, and handed down their pungency to future generations. Just in the same way nettles have acquired their sting and thistles their prickles, which efficiently protect them against all herbivores, except the patient, hungry donkey, who gratefully accepts them as a sort of *sauce piquante* to the succulent stems.

And now the arum begins its great preparations for the act of flowering. Everybody knows the general shape of the arum blossom—if not in our own purple cuckoo-pint, at least in the big white "Ethiopian lilies" which form such frequent ornaments of cottage windows. Clearly, this is a flower which the plant cannot produce without laying up a good stock of material beforehand. So its sets to work accumulating starch in its root. This starch it manufactures in its leaves, and then buries deep under ground in a tuber, by means of the sap, so as to secure it from the attacks of rodents, who too frequently appropriate to themselves the food intended by plants for other purposes. If you examine the tuber before the arum has blossomed, you will find it large and solid; but if you dig it up in the autumn after the seeds have ripened, you will see that it is flaccid and drained; all its starches and other contents have gone to make up the flower, the fruit, and the stalk which bore them. But the tuber has a further protection against enemies besides its deep underground position. It contains an acrid juice like that of the leaves, which sufficiently guards it against four-footed depredators. Man, however, that most persistent of persecutors, has found out a way to separate the juice from the starch; and in St. Helena the big white arum is cultivated as a food-plant, and yields the meal in common use among the inhabitants.

When the arum has laid by enough starch to make a flower it begins to send up a tall stalk, on the top of which grows the curious hooded blossom known to be one of the earliest forms still surviving upon earth. But now its object is to attract, not to repel, the animal world; for it is an insect-fertilized flower, and it requires the aid of small flies to carry the pollen from blossom to blossom. For this purpose it has a purple sheath around its head of flowers and a tall spike on which they are arranged in two clusters, the male blossoms above and the female below. This spike is bright yellow in the cultivated species. The fertilization is one of the most interesting episodes in all nature, but it would take too long to describe here in full. The flies go from one arum to another, attracted by the color, in search of pollen; and the pistils, or female flowers, ripen first. Then the pollen falls from the stamens or male flowers on the bodies of the flies, and dusts them all over with yellow powder. The insects, when once they have entered, are imprisoned until the pollen is ready to drop, by means of several little hairs, pointing downward, and preventing their exit on the principle of an eel-trap or lobster-pot. But as soon as the pollen is discharged the hairs wither away, and then the flies are free to visit a second arum. Here they carry the fertilizing dust with which they are covered to the ripe pistils, and so enable them to set their seed; but, instead of getting away again as soon as they have eaten their fill, they are once more imprisoned by the lobster-pot hairs, and dusted with a

second dose of pollen, which they carry away in turn to a third blossom.

As soon as the pistils have been impregnated, the fruits begin to set. Here they are, on their tall spike, whose inclosing sheath has now withered away, while the top is at this moment slowly dwindling, so that only the cluster of berries at its base will finally remain. The berries will swell and grow soft, till in autumn they become a beautiful scarlet cluster of living coral. Then once more their object will be to attract the animal world, this time in the shape of field-mice, squirrels, and small birds; but with a more treacherous intent. For though the berries are beautiful and palatable enough they are deadly poison. The robins or small rodents which eat them, attracted by their bright colors and pleasant taste, not only aid in dispersing them, but also die after swallowing them, and become huge manure heaps for the growth of the young plant. So the whole cycle of arum existence begins afresh, and there is hardly a plant in the field around me which has not a history as strange as this one.

IX.

BERRIES AND BERRIES.

This little chine, opening toward the sea through the blue lias cliffs, has been worn to its present pretty gorge-like depth by the slow action of its tiny stream—a mere thread of water in fine weather, that trickles down its centre in a series of mossy cascades to the shingly beach below. Its sides are overgrown by brambles and other prickly brushwood, which form in places a matted and impenetrable mass; for it is the habit of all plants protected by the defensive armor of spines or thorns to cluster together in serried ranks, through which cattle or other intrusive animals cannot break. Among them, near the down above, I have just lighted upon a rare plant for Southern Britain—a wild raspberry-bush in full fruit. Raspberries are common enough in Scotland among heaps of stones on the windiest hillsides; but the south of England is too warm and sickly for their robust tastes, and they can only be found here in a few bleak spots like the stony edges of this weather-beaten down above the chine. The fruit itself is quite as good as the garden variety, for cultivation has added little to the native virtues of the raspberry. Good old Izaac Walton is not ashamed to quote a certain quaint saying of one Dr. Boteler concerning strawberries, and so I suppose I need not be afraid to quote it after him. "Doubtless," said the Doctor, "God *could* have made a better berry, but doubtless also God never did." Nevertheless, if you try the raspberry, picked fresh, with plenty of good country cream, you must allow that it runs its sister fruit a neck-and-neck race.

To compare the structure of a raspberry with that of a strawberry is a very instructive botanical study. It shows how similar causes may produce the same gross result in singularly different ways. Both are roses by family, and both have flowers essentially similar to that of the common dog-rose. But even in plants where the flowers are alike, the fruits often differ conspicuously, because fresh principles come into play for the dispersion and safe germination of the seed. This makes the study of fruits the most complicated part in the unravelling of plant life. After the strawberry has blossomed, the pulpy receptacle on which it bore its green fruitlets begins to swell and redden, till at length it grows into an edible berry, dotted with little yellow nuts, containing each a single seed. But in the raspberry it is the separate fruitlets themselves which grow soft and bright-colored, while the receptacle remains white and tasteless, forming the "hull" which we pull off from the berry when we are going to eat it. Thus the part of the raspberry which we throw away answers to the part of the strawberry which we eat. Only, in the raspberry the separate fruitlets are all crowded close together into a single united mass, while in the strawberry they are scattered about loosely, and imbedded in the soft flesh of the re-

ceptacle. The blackberry is another close relative; but in its fruit the little pulpy fruitlets cling to the receptacle, so that we pick and eat them both together; whereas in the raspberry the receptacle pulls out easily, and leaves a thimble-shaped hollow in the middle of the berry. Each of these little peculiarities has a special meaning of its own in the history of the different plants.

Yet the main object attained by all is in the end precisely similar. Strawberries, raspberries, and blackberries all belong to the class of attractive fruits. They survive in virtue of the attention paid to them by birds and small animals. Just as the wild strawberry which I picked in the hedgerow the other day procures the dispersion of its hard and indigestible fruitlets by getting them eaten together with the pulpy receptacle, so does the raspberry procure the dispersion of its soft and sugary fruitlets by getting them eaten all by themselves. While the strawberry fruitlets retain throughout their dry outer coating, in those of the raspberry the external covering becomes fleshy and red, but the inner seed has, notwithstanding, a still harder shell than the tiny nuts of the strawberry. Now, this is the secret of nine fruits out of ten. They are really nuts, which clothe themselves in an outer tunic of sweet and beautifully colored pulp. The pulp as it were, the plant gives in, as an inducement to the friendly bird to swallow its seed; but the seed itself it protects by a hard stone or shell, and often by poisonous or bitter juices within. We see this arrangement very conspicuously in a plum, or still better in a mango; though it is really just as evident in the raspberry, where the smaller size renders it less conspicuous to human sight.

It is a curious fact about the rose family that they have a very marked tendency to produce such fleshy fruits, instead of the mere dry seed-vessels of ordinary plants, which are named fruits only by botanical courtesy. For example, we owe to this single family the peach, plum, apricot, cherry, damson, pear, apple, medlar, and quince, all of them cultivated in gardens or orchards for their fruits. The minor group known by the poetical name of Dryads, alone supplies us with the strawberry, raspberry, blackberry, and dewberry. Even the wilder kinds, refused as food by man, produce berries well known to our winter birds—the haw, rose-hip, sloe, bird-cherry, and rowan. On the other hand, the whole tribe numbers but a single thoroughgoing nut—the almond; and even this nut, always somewhat soft-shelled and inclined to pulpiness, has produced by a "sport" the wholly fruit-like nectarine. The odd thing about the rose tribe, however, is this: that the pulpy tendency shows itself in very different parts among the various species. In the plum it is the outer covering of the true fruit which grows soft and colored; in the apple it is a swollen mass of the fruit-stalk surrounding the ovules; in the rose-hip it is the hollowed receptacle; and in the strawberry it is the same receptacle, bulging out in the opposite direction. Such a general tendency to display color and collect sugary juices in so many diverse parts may be compared to the general bulbous tendency of the tiger-lily or the onion, and to the general succulent tendency of the cactus or the house-leek. In each case, the plant benefits by it in one form or another; and whichever form happens to get the start in any particular instance is increased and developed by natural selection, just as favorable varieties of fruits or flowers are increased and developed in cultivated species by our own gardeners.

Sweet juices and bright colors, however, could be of no use to a plant till there were eyes to see and tongues to taste them. A pulpy fruit is in itself a mere waste of productive energy to its mother, unless the pulpiness aids in the dispersion and promotes the welfare of the young seedlings. Accordingly, we might naturally expect that there would be no fruit-bearers on the earth until the time when fruit-eaters, actual or potential, arrived upon the scene; or, to put it more correctly, both must inevitably have developed simultaneously and in mutual dependence upon one

another. So we find no traces of succulent fruits even in so late a formation as that of these lias or cretaceous cliffs. The birds of that day were fierce-toothed carnivores, devouring the lizards and saurians of the rank low-lying sea-marshes ; the mammals were most primeval kangaroos or low ancestral wombats, gentle herbivores, or savage marsupial wolves, like the Tasmanian devil of our own times. It is only in the very modern tertiary period, whose soft muddy deposits have not yet had time to harden under superincumbent pressure into solid stone, that we find the earliest traces of the rose family, the greatest fruit-bearing tribe of our present world. And side by side with them we find their clever aboreal allies, the ancestral monkeys and squirrels, the primitive robins, and the yet shadowy forefathers of our modern fruit-eating parrots. Just as bees and butterflies necessarily trace back their geological history only to the time of the first honey-bearing flowers, and just as the honey-bearing flowers in turn trace back their pedigree only to the date of the rudest and most unspecialized honey-sucking insects, so are fruits and fruit-eaters linked together in origin by the inevitable bond of a mutual dependence. No bee, no honey ; and no honey, no bee : so, too, no fruit, no fruit-bird ; and no fruit-bird, no fruit.

X.

DISTANT RELATIONS.

Behind the old mill, whose overshot wheel, backed by a wall thickly covered with the young creeping fronds of hart's-tongue ferns, forms such a picturesque foreground for the view of our little valley, the mill-stream expands into a small, shallow pond, overhung at its edges by thick-set hazel-bushes and clambering honeysuckle. Of course it is only dammed back by a mud wall, with sluices for the miller's water-power ; but it has a certain rustic simplicity of its own, which makes it beautiful to our eyes for all that, in spite of its utilitarian origin. At the bottom of this shallow pond you may now see a miracle daily taking place, which but for its commonness we should regard as an almost incredible marvel. You may there behold evolution actually illustrating the transformation of life under your very eyes : you may watch a low type of gill-breathing gristly-boned fish developing into the highest form of lung-breathing terrestrial amphibian. Nay, more—you may almost discover the earliest known ancestor of the whole vertebrate kind, the first cousin of that once famous ascidian larva, passing through all the upward stages of existence which finally lead it to assume the shape of a relatively perfect four-legged animal. For the pond is swarming with fat black tadpoles, which are just at this moment losing their tails and developing their legs, on the way to becoming fully formed frogs.

The tadpole and the ascidian larva divide between them the honor of preserving for us in all its native simplicity the primitive aspect of the vertebrate type. Beasts, birds, reptiles, and fishes have all descended from an animal whose shape closely resembled that of these wriggling little black creatures which dart up and down like imps through the clear water, and raise a cloud of mud above their heads each time that they bury themselves comfortably in the soft mud of the bottom. But while the birds and beasts, on the one hand, have gone on bettering themselves out of all knowledge, and while the ascidian, on the other hand, in his adult form has dropped back into an obscure and sedentary life—sans eyes, sans teeth, sans taste, sans everything—the tadpole alone, at least during its early days, remains true to the ancestral traditions of the vertebrate family. When first it emerges from its egg it represents the very most rudimentary animal with a backbone known to our scientific teachers. It has a big hammer-looking head, and a set of branching outside gills, and a short distinct body, and a long semi-transparent tail. Its backbone is a mere gristly channel, in which lies its spinal cord. As it grows, it resembles in every particular the ascidian larva, with which, indeed,

Kowalewsky and Professor Ray Lankester have demonstrated its essential identity. But since a great many people seem wrongly to imagine that Professor Lankester's opinion on this matter is in some way at variance with Mr. Darwin's and Dr. Haeckel's, it may be well to consider what the degeneracy of the ascidian really means. The fact is, both larval forms—that of the frog and that of the ascidian—completely agree in the position of their brains, their gill-slits, their very rudimentary backbones, and their spinal cords. Moreover, we ourselves and the tadpole agree with the ascidian in a further most important point, which no invertebrate animal shares with us ; and that is that our eyes grow out of our brains, instead of being part of our skin, as in insects and cuttle-fish. This would seem *à priori* a most inconvenient place for an eye—inside the brain ; but then, as Professor Lankester cleverly suggests, our common original ancestor, the very earliest vertebrate of all, must have been a transparent creature, and therefore comparatively indifferent as to the part of his body in which his eye happened to be placed. In after ages, however, as vertebrates generally got to have thicker skulls and tougher skins, the eye-bearing part of the brain had to grow outward, and so reach the light on the surface of the body : a thing which actually happens to all birds, beasts, and reptiles in the course of their embryonic development. So that in this respect the ascidian larva is nearer to the original type than the tadpole or any other existing animal.

The ascidian, however, in mature life, has grown degraded and fallen from his high estate, owing to his bad habit of rooting himself to a rock and there settling down into a mere sedentary swallower of passing morsels—a blind, handless, footless, and degenerate thing. In his later shape he is but a sack fixed to a stone, and with all his limbs and higher sense-organs so completely atrophied that only his earlier history allows us to recognize him as a vertebrate by descent at all. He is in fact a representative of retrogressive development. The tadpole, on the contrary, goes on swimming about freely, and keeping the use of its eyes, till at last a pair of hind legs and then a pair of fore legs begin to bud out from its side, and its tail fades away, and its gills disappear, and air-breathing lungs take their place, and it boldly hops on shore a fully evolved tailless amphibian.

There is, however, one interesting question about these two larvæ which I should much like to solve. The ascidian has only *one* eye inside its useless brain, while the tadpole and all other vertebrates have *two* from the very first. Now which of us most nearly represents the old mud-loving vertebrate ancestor in this respect ? Have two original organs coalesced in the young ascidian, or has one organ split up into a couple with the rest of the class ? I think the latter is the true supposition, and for this reason : In our heads, and those of all vertebrates, there is a curious cross-connection between the eyes and the brain, so that the right optic nerve goes to the left side of the brain and the left optic nerve goes to the right side. In higher animals, this "decussation," as anatomists call it, affects all the sense-organs except those of smell ; but in fishes it only affects the eyes. Now, as the young ascidian has retained the ancestral position of his almost useless eye so steadily, it is reasonable to suppose that he has retained its other peculiarities as well. May we not conclude, therefore, that the primitive vertebrate had only one brain-eye ; but that afterward, as this brain-eye grew outward to the surface, it split up into two, because of the elongated and flattened form of the head in swimming animals, while its two halves still kept up a memory of their former union in the cross-connection with the opposite halves of the brain ? If this be so, then we might suppose that the other organs followed suit, so as to prevent confusion in the brain between the two sides of the body ; while the nose, which stands in the centre of the face, was under no liability to such error, and therefore still keeps up its primitive direct arrangement.

It is worth noting, too, that these tadpoles, like all other very low vertebrates, are mud-haunters ; and the most primitive among adult vertebrates are still cartilaginous mud-fish. Not much is known geologically about the predecessors of frogs ; the tailless amphibians are late arrivals upon earth, and it may seem curious, therefore, that they should recall in so many ways the earliest ancestral type. The reason doubtless is because they are so much given to larval development. Some ancestors of theirs—primeval newts or salamanders—must have gone on for countless centuries improving themselves in their adult shape from age to age, yet bringing all their young into the world from the egg, as mere mud-fish still, in much the same state as their unimproved forefathers had done millions of æons before. Similarly, caterpillars are still all but exact patterns of the primeval insect, while butterflies are totally different and far higher creatures. Thus, in spite of adult degeneracy in the ascidian and adult progress in the frog, both tadpoles preserve for us very nearly the original form of their earliest backboned ancestor. Each individual recapitulates in its own person the whole history of evolution in its race. This is a very lucky thing for biology ; since without these recapitulatory phases we could never have traced the true lines of descent in many cases. It would be a real misfortune for science if every frog had been born a typical amphibian, as some tree-toads actually are, and if every insect had emerged a fully formed adult, as some aphides very nearly do. Larvæ and embryos show us the original types of each race : adults show us the total amount of change produced by progressive or retrogressive development.

XI.

AMONG THE HEATHER.

This is the worst year for butterflies that I can remember. Entomologists all over England are in despair at the total failure of the insect crop, and have taken to botanizing, angling, and other bad habits, in default of means for pursuing their natural avocation as beetle-stickers. Last year's heavy rains killed all the mothers as they emerged from the chrysalis ; and so only a few stray eggs have survived till this summer, when the butterflies they produce will all be needed to keep up next season's supply. Nevertheless, I have climbed the highest down in this part of the country to-day, and come out for an airing among the heather, in the vague hope that I may be lucky enough to catch a glimpse of one or two old lepidopterous favorites. I am not a butterfly-hunter myself. I have not the heart to drive pins through the pretty creatures' downy bodies, or to stifle them with reeking chemicals ; though I recognize the necessity for a hardened class who will perform that useful office on behalf of science and society, just as I recognize the necessity for slaughtermen and knackers. But I prefer personally to lie on the ground at my ease and learn as much about the insect nature as I can discover from simple inspection of the living subject as it flits airily from bunch to bunch of bright-colored flowers.

I suppose even that apocryphal person, the general reader, would be insulted at being told at this hour of the day that all bright-colored flowers are fertilized by the visits of insects, whose attentions they are specially designed to solicit. Everybody has heard over and over again that roses, orchids, and columbines have acquired their honey to allure the friendly bee, their gaudy petals to advertise the honey, and their divers shapes to insure the proper fertilization by the correct type of insect. But everybody does not know how specifically certain blossoms have laid themselves out for a particular species of fly, beetle, or tiny moth. Here on the higher downs, for instance, most flowers are exceptionally large and brilliant ; while all Alpine climbers must have noticed that the most gorgeous masses of bloom in Switzerland occur just below the snow-line. The reason is, that such blossoms must be fertilized by butterflies alone. Bees, their great

rivals in honey-sucking, frequent only the lower meadows and slopes, where flowers are many and small: they seldom venture far from the hive or the nest among the high peaks and chilly nooks where we find those great patches of blue gentian or purple anemone, which hang like monstrous breadths of tapestry upon the mountain sides. This heather here, now fully opening in the warmer sun of the southern counties—it is still but in the bud among the Scotch hills, I doubt not—specially lays itself out for the humble-bee, and its masses form about his highest pasture-grounds; but the butterflies—insect vagrants that they are—have no fixed home, and they therefore stray far above the level at which bee-blossoms altogether cease to grow. Now, the butterfly differs greatly from the bee in his mode of honey-hunting; he does not bustle about in a business-like manner from one buttercup or dead-nettle to its nearest fellow; but he flits joyously, like a sauntering straggler that he is, from a great patch of color here to another great patch at a distance, whose gleam happens to strike his roving eye by its size and brilliancy. Hence, as that indefatigable observer, Dr. Hermann Müller has noticed, all Alpine or hill-top flowers have very large and conspicuous blossoms, generally grouped together in big clusters so as to catch a passing glance of the butterfly's eye. As soon as the insect spies such a cluster, the color seems to act as a stimulant to his broad wings, just as the candle-light does to those of his cousin the moth. Off he sails at once, as if by automatic action, toward the distant patch, and there both robs the plant of its honey and at the same time carries to it on his legs and head fertilizing pollen from the last of its congeners which he favored with a call. For of course both bees and butterflies stick on the whole to a single species at a time; or else the flowers would only get uselessly hybridized instead of being impregnated with pollen from other plants of their own kind. For this purpose it is that most plants lay themselves out to secure the attention of only two or three varieties among their insect allies, while they make their nectaries either too deep or too shallow for the convenience of all other kinds. Nature, though eager for cross-fertilization, abhors "miscegenation" with all the bitterness of an American politician.

Insects, however, differ much from one another in their æsthetic tastes, and flowers are adapted accordingly to the varying fancies of the different kinds. Here, for example, is a spray of common white galium, which attracts and is fertilized by small flies, who generally frequent white blossoms. But here, again, not far off, I find a luxuriant mass of the yellow species, known by the quaint name of "lady's bedstraw"—a legacy from the old legend which represents it as having formed Our Lady's bed in the manger at Bethlehem. Now why has this kind of galium yellow flowers, while its near kinsman yonder has them snowy white? The reason is that lady's bedstraw is fertilized by small beetles; and beetles are known to be one among the most color-loving races of insects. You may often find one of their number, the lovely, bronze and golden-mailed rose-chafer, buried deeply in the very centre of a red garden rose, and reeling about when touched as if drunk with pollen and honey. Almost all the flowers which beetles frequent are consequently brightly decked in scarlet or yellow. On the other hand, the whole family of the umbellates, those tall plants with level bunches of tiny blossoms, like the fool's parsley, have all but universally white petals; and Müller, the most statistical of naturalists, took the trouble to count the number of insects which paid them a visit. He found that only 14 per cent were bees, while the remainder consisted mainly of miscellaneous small flies and other arthropodous riff-raff; whereas in the brilliant class of composites, including the asters, sunflowers, daisies, dandelions, and thistles, nearly 75 per cent of the visitors were steady, industrious bees. Certain dingy blossoms which lay themselves out to attract wasps are obviously adapted, as Müller quaintly remarks, "to a less

æsthetically cultivated circle of visitors." But the most brilliant among all insect-fertilized flowers are those which specially affect the society of butterflies; and they are only surpassed in this respect throughout all nature by the still larger and more magnificent tropical species which owe their fertilization to humming-birds and brush-tongued lories.

Is it not a curious, yet a comprehensible circumstance, that the tastes which thus show themselves in the development, by natural selection, of lovely flowers, should also show themselves in the marked preference for beautiful mates? Poised on yonder sprig of harebell stands a little purple-winged butterfly, one of the most exquisite among our British kinds. That little butterfly owes its own rich and delicately shaded tints to the long selective action of a million generations among its ancestors. So we find throughout that the most beautifully colored birds and insects are always those which have had most to do with the production of bright-colored fruits and flowers. The butterflies and rose-beetles are the most gorgeous among insects; the humming-birds and parrots are the most gorgeous among birds. Nay, more: exactly like effects have been produced in two hemispheres on different tribes by the same causes. The plain brown swifts of the North have developed among tropical West Indian and South American orchids the metallic gorgets and crimson crests of the humming-bird; while a totally unlike group of Asiatic birds have developed among the rich flora of India and the Malay Archipelago the exactly similar plumage of the exquisite sun-birds. Just as bees depend upon flowers, and flowers upon bees, so the color-sense of animals has created the bright petals of blossoms; and the bright petals have reacted upon the tastes of the animals themselves, and through their tastes upon their own appearance.

XII.

SPECKLED TROUT.

It is a piece of the common vanity of anglers to suppose that they know something about speckled trout. A fox might almost as well pretend that he was intimately acquainted with the domestic habits of poultry, or an Iroquois describe the customs of the Algonquins from observations made upon the specimens who had come under his scalping-knife. I will allow that anglers are well versed in the necessity for fishing up-stream rather than in the opposite direction; and I grant that they have attained an empirical knowledge of the æsthetic preferences of trout in the matter of blue duns and red palmers; but that as a body they are familiar with the speckled trout at home I deny. If you wish to learn all about the race in its own life you must abjure rod and line, and creep quietly to the side of the pools in an unfished brooklet, like this on whose bank I am now seated; and then, if you have taken care not to let your shadow fall upon the water, you may sit and watch the live fish themselves for an hour together, as they bask lazily in the sunlight, or rise now and then at cloudy moments with a sudden dart at a May-fly who is trying in vain to lay her eggs unmolested on the surface of the stream. The trout in my little beck are fortunately too small even for poachers to care for tickling them; so I am able entirely to preserve them as objects for philosophical contemplation, without any danger of their being scared away from their accustomed haunts by intrusive anglers.

Trout always have a recognized home of their own, inhabited by a pretty fixed number of individuals. But if you catch the two sole denizens of a particular scour, you will find another pair installed in their place to-morrow. Young fry seem always ready to fill up the vacancies caused by the involuntary retirement of their elders. Their size depends almost entirely upon the quantity of food they can get; for an adult fish may weigh anything at any time of his life, and there is no limit to the dimensions they may theoretically attain. Mr. Herbert Spencer, who is an angler as well as a philosopher, well observes that where the trout are many

they are generally small; and where they are large they are generally few. In the mill-stream down the valley they measure only six inches, though you may fill a basket easily enough on a cloudy day; but in the canal reservoir, where there are only half a dozen fish altogether, a magnificent eight-pounder has been taken more than once. In this way we can understand the origin of the great lake trout, which weigh sometimes forty pounds. They are common trout which have taken to living in broader waters, where large food is far more abundant, but where shoals of small fish would starve. The peculiarities thus impressed upon them have been handed down to their descendants, till at length they have become sufficiently marked to justify us in regarding them as a separate species. But it is difficult to say what makes a species in animals so very variable as fish. There are, in fact, no less than twelve kinds of trout wholly peculiar to the British Islands, and some of these are found in very restricted areas. Thus, the Loch Stennis trout inhabits only the tarns of Orkney; the Galway sea trout lives nowhere but along the west coast of Ireland; the gillaroo never strays out of the Irish loughs; the Killin charr is confined to a single sheet of water in Mayo; and other species belong exclusively to the Llanberis lakes, to Lough Melvin, or to a few mountain pools of Wales and Scotland. So great is the variety that may be produced by small changes of food and habitat. Even the salmon himself is only a river trout who has acquired the habit of going down to the sea, where he gets immensely increased quantities of food (for all the trout kind are almost omnivorous), and grows big in proportion. But he still retains many marks of his early existence as a river fish. In the first place, every salmon is hatched from the egg in fresh water, and grows up a mere trout. The young parr, as the salmon is called in this stage of its growth, is actually (as far as physiology goes) a mature fish, and is capable of producing milt, or male spawn, which long caused it to be looked upon as a separate species. It really represents, however, the early form of the salmon, before he took to his annual excursion to the sea. The ancestral fish, only a hundredth fraction in weight of his huge descendant, must have somehow acquired the habit of going seaward—possibly from a drying up of his native stream in seasons of drought. In the sea, he found himself suddenly supplied with an unwonted store of food, and grew, like all his kind under similar circumstances, to an extraordinary size. Thus he attains, as it were, to a second and final maturity. But salmon cannot lay their eggs in the sea; or at least, if they did, the young parr would starve for want of their proper food, or else be choked by the salt water, to which the old fish have acclimatized themselves. Accordingly, with the return of the spawning season there comes back an instinctive desire to seek once more the native fresh water. So the salmon return up stream to spawn, and the young are hatched in the kind of surroundings which best suit their tender gills. This instinctive longing for the old home may probably have arisen during an intermediate stage, when the developing species still haunted only the brackish water near the river mouths; and as those fish alone which returned to the head waters could preserve their race, it would soon grow hardened into a habit ingrained in the nervous system, like the migration of birds or the clustering of swarming bees around their queen. In like manner the Jamaican land-crabs, which themselves live on the mountain-tops, come down every year to lay their eggs in the Caribbean; because, like all other crabs, they pass their first larval stage as swimming tadpoles, and afterward take instinctively to the mountains, as the salmon takes to the sea. Such a habit could only have arisen by one generation after another venturing farther and farther inland, while always returning at the proper season to the native element for the deposition of the eggs.

These trout here, however, differ from the salmon in one important particular besides their relative size, and

that is that they are beautifully speckled in their mature form, instead of being merely silvery like the larger species. The origin of the pretty speckles is probably to be found in the constant selection by the fish of the most beautiful among their number as mates. Just as singing-birds are in their fullest and clearest song at the nesting period, and just as many brilliant species only possess their gorgeous plumage while they are going through their courtship, and lose the decoration after the young brood is hatched, so the trout are most brightly colored at spawning time, and become lank and dingy after the eggs have been safely deposited. The parent fish ascend to the head-waters of their native river during the autumn season to spawn, and then, their glory dimmed, they return down-stream to the deep pools, where they pass the winter sulkily, as if ashamed to show themselves in their dull and dusky suits. But when spring comes round once more, and flies again become abundant, the trout begin to move upstream afresh, and soon fatten out to their customary size and brilliant colors. It might seem at first sight that creatures so humble as these little fish could hardly have sufficiently developed æsthetic tastes to prefer one mate above another on the score of beauty. But we must remember that every species is very sensitive to small points of detail in its own kind, and that the choice would only be exerted between mates generally very like one another, so that extremely minute differences must necessarily turn the scale in favor of one particular suitor rather than his rivals. Anglers know that trout are attracted by bright colors, that they can distinguish the different flies upon which they feed, and that artificial flies must accordingly be made at least into a rough semblance of the original insects. Some scientific fishermen even insist that it is no use offering them a brown drake at the time of year or the hour of day when they are naturally expecting a red spinner. Of course their sight is by no means so perfect as our own, but it probably includes a fair idea of form, and an acute perception of color, while there is every reason to believe that all the trout family have a decided love of metallic glitter, such as that of silver or of the salmon's scales. Mr. Darwin has shown that the little stickleback goes through an elaborate courtship, and I have myself watched trout which seemed to me as obviously love-making as any pair of turtle-doves I ever saw. In their early life salmon fry and young trout are almost quite indistinguishable, being both marked with blue patches (known as "finger-marks") on their sides, which are remnants of the ancestral coloring once common to the whole race. But as they grow up, their later-acquired tastes begin to produce a divergence, due originally to this selective preference of certain beautiful mates ; and the adult salmon clothes himself from head to tail in sheeny silver, while the full-grown trout decks his sides with the beautiful speckles which have earned him his popular name. Countless generations of slight differences, selected from time to time by the strongest and handsomest fish, have sufficed at length to bring about these conspicuous variations from the primitive type, which the young of both races still preserve.

XIII.

DODDER AND BROOMRAPE.

This afternoon, strolling through the undercliff, I have come across two quaint and rather uncommon flowers among the straggling brushwood. One of them is growing like a creeper around the branches of this overblown gorse-bush. It is the lesser dodder, a pretty clustering mass of tiny pale pink convolvulus blossoms. The stem consists of a long red thread, twining round and round the gorse, and bursting out here and there into thick bundles of beautiful bell-shaped flowers. But where are the leaves ? You may trace the red threads through their labyrinthine windings up and down the supporting gorse-branches all in vain : there is not a leaf to be seen. As a matter of fact, the dodder has none. It is one of the

most thoroughgoing parasites in all nature. Ordinary green-leaved plants live by making starches for themselves out of the carbonic acid in the air, under the influence of sunlight ; but the dodder simply fastens itself on to another plant, sends down rootlets or suckers into its veins, and drinks up sap stored with ready-made starches or other food-stuffs, originally destined by its host for the supply of its own growing leaves, branches, and blossoms. It lives upon the gorse just as parasitically as the little green aphides live upon our rose-bushes. The material which it uses up in pushing forth its long thread-like stem and clustered bells is so much dead loss to the unfortunate plant on which it has fixed itself.

Old-fashioned books tell us that the mistletoe is a perfect parasite, while the dodder is an imperfect one ; and I believe almost all botanists will still repeat the foolish saying to the present day. But it really shows considerable haziness as to what a true parasite is. The mistletoe is a plant which has taken, it is true, to growing upon other trees. Its very viscid berries are useful for attaching the seeds to the trunk of the oak or the apple ; and there it roots itself into the body of its host. But it soon produces real green leaves of its own, which contain the ordinary chlorophyl found in other leaves, and help it to manufacture starch, under the influence of sunlight, on its own account. It is not, therefore, a complete drag upon the tree which it infests ; for though it takes sap and mineral food from the host, it supplies itself with carbon, which is after all the important thing for plant-life. Dodder, however, is a parasite pure and simple. Its seeds fall originally upon the ground, and there root themselves at first like those of any other plant. But, as it grows, its long twining stem begins to curl for support round some other and stouter stalk. If it stopped there, and then produced leaves of its own, like the honeysuckle and the clematis, there would be no great harm done ; and the dodder would be but another climbing plant the more in our flora. However, it soon insidiously repays the support given it by sending down little bud-like suckers, through which it draws up nourishment from the gorse or clover on which it lives. Thus it has no need to develop leaves of its own ; and it accordingly employs all its stolen material in sending forth matted thread-like stems and bunch after bunch of bright flowers. As these increase and multiply, they at last succeed in drawing away all the nutriment from the supporting plant, which finally dies under the constant drain, just as a horse might die under the attacks of a host of leeches. But this matters little to the dodder, which has had time to be visited and fertilized by insects, and to set and ripen its numerous seeds. One species, the greater dodder, is thus parasitic upon hops and nettles ; a second kind twines round flax ; and the third, which I have here under my eyes, mainly confines its dangerous attentions to gorse, clover, and thyme. All of them are, of course, deadly enemies to the plants they infest.

How the dodder acquired this curious mode of life it is not difficult to see. By descent it is a bind-weed, or wild convolvulus, and its blossoms are in the main miniature convolvulus blossoms still. Now, all bind-weeds, as everybody knows, are climbing plants, which twine themselves round stouter stems for mere physical support. This is in itself a half-parasitic habit, because it enables the plant to dispense with the trouble of making a thick and solid stem for its own use. But just suppose that any bind-weed, instead of merely twining, were to put forth here and there little tendrils, something like those of the ivy, which managed somehow to grow into the bark of the host, and so naturally graft themselves to its tissues. In that case the plant would derive nutriment from the stouter stem with no expense to itself, and it might naturally be expected to grow strong and healthy, and hand down its peculiarities to its descendants. As the leaves would thus be rendered needless, they would first become very much reduced in size, and would finally disappear altogether,

according to the universal custom of unnecessary organs. So we should get at length a leafless plant, with numerous flowers and seeds, just like the dodder. Parasites, in fact, whether animal or vegetable, always end by becoming mere reproductive sacs, mechanisms for the simple elaboration of eggs or seeds. This is just what has happened to the dodder before me.

The other queer plant here is a broomrape. It consists of a tall, somewhat faded-looking stem, upright instead of climbing, and covered with brown or purplish scales in the place of leaves. Its flowers resemble the scales in color, and the dead-nettle in shape. It is, in fact, a parasitic dead-nettle, a trifle less degenerate as yet than the dodder. This broomrape has acquired somewhat the same habits as the other plant, only that it fixes itself on the roots of clover or broom, from which it sucks nutriment by its own root, as the dodder does by its stem-suckers. Of course it still retains in most particulars its original characteristics as a dead-nettle ; it grows with their upright stem and their curiously shaped flowers, so specially adapted for fertilization by insect visitors. But it has naturally lost its leaves, for which it has no further use, and it possesses no chlorophyl, as the mistletoe does. Yet it has not probably been parasitic for as long a time as the dodder, since it still retains a dwindling trace of its leaves in the shape of dry purply scales, something like those of young asparagus shoots. These leaves are now, in all likelihood, actually undergoing a gradual atrophy, and we may fairly expect that in the course of a few thousand years they will disappear altogether. At present, however, they remain very conspicuous by their color, which is not green, owing to the absence of chlorophyl, but is due to the same pigment as that of the blossoms. This generally happens with parasites, or with that other curious sort of plants known as saprophytes, which live upon decaying living matter in the mould of forests. As they need no green leaves, but have often inherited leafy structures of some sort, in a more or less degenerate condition, from their self-supporting ancestors, they usually display most beautiful colors in their stems and scales, and several of them rank among our handsomest hothouse plants. Even the dodder has red stalks. Their only work in life being to elaborate the materials stolen from their host into the brilliant pigments used in the petals for attracting insect fertilizers, they pour this same dye into the stems and scales, which thus render them still more conspicuous to the insects' eyes. Moreover, as they use their whole material in producing flowers, many of these are very large and handsome ; one huge Sumatran species has a blossom which measures three feet across. On the other hand, their seeds are usually small and very numerous. Thousands of seeds must fall on unsuitable places, spring up, and waste all their tiny store of nourishment, find no host at hand on which to fasten themselves, and so die down for want of food. It is only by producing a few thousand young plants for every one destined ultimately to survive that dodders and broomrapes manage to preserve their types at all.

XIV.

DOG'S MERCURY AND PLANTAIN.

THE hedge and bank in Haye Lane are now a perfect tangled mass of creeping plants, among which I have just picked out a queer little three-cornered flower, hardly known even to village children, but christened by our old herbalists "dog's mercury." It is an ancient trick of language to call coarser or larger plants by the specific title of some smaller or cultivated kind, with the addition of an animal's name. Thus we have radish and horse-radish, chestnut and horse-chestnut, rose and dog-rose, parsnip and cow-parsnip, thistle and sow-thistle. On the same principle, a somewhat similar plant being known as mercury, this perennial weed becomes dog's mercury. Both, of course, go back to some imaginary medicinal virtue in the herb which made it resemble the metal in the eyes of old-fashioned practitioners.

Dog's mercury is one of the oddest English flowers I know. Each blossom has three small green petals, and either several stamens, or else a pistil, in the centre. There is nothing particularly remarkable in the flower being green, for thousands of other flowers are green and we never notice them as in any way unusual. In fact, we never as a rule notice green blossoms at all. Yet anybody who picked a piece of dog's mercury could not fail to be struck by its curious appearance. It does not in the least resemble the inconspicuous green flowers of the stinging-nettle, or of most forest trees : it has a very distinct set of petals which at once impress one with the idea that they ought to be colored. And so indeed they ought : for dog's mercury is a degenerate plant which once possessed a brilliant corolla and was fertilized by insects, but which has now fallen from its high estate and reverted to the less advanced mode of fertilization by the intermediation of the wind. For some unknown reason or other this species and all its relations have discovered that they get on better by the latter and usually more wasteful plan than by the former and usually more economical one. Hence they have given up producing large bright petals, because they no longer need to attract the eyes of insects ; and they have also given up the manufacture of honey, which under their new circumstances would be a mere waste of substance to them. But the dog's mercury still retains a distinct mark of its earlier insect-attracting habits in these three diminutive petals. Others of its relations have lost even these, so that the original floral form is almost completely obscured in their case. The spurges are familiar English roadside examples, and their flowers are so completely degraded that even botanists for a long time mistook their nature and analogies.

The male and female flowers of dog's mercury have taken to living upon separate plants. Why is this ? Well, there was no doubt a time when every blossom had both stamens and pistil, as dog-roses and buttercups always have. But when the plant took to wind fertilization it underwent a change of structure. The stamens on some blossoms became aborted, while the pistil became aborted on others. This was necessary in order to prevent self-fertilization ; for otherwise the pollen of each blossom, hanging out as it does to the wind, would have been very liable to fall upon its own pistil. But the present arrangement obviates any such contingency, by making one plant bear all the male flowers and another plant all the female ones. Why, again, are the petals green ? I think because dog's mercury would be positively injured by the visits of insects. It has no honey to offer them, and if they came to it at all, they would only eat up the pollen itself. Hence I suspect that those flowers among the mercuries which showed any tendency to retain the original colored petals would soon get weeded out, because insects would eat up all their pollen, thus preventing them from fertilizing others ; while those which had green petals would never be noticed and so would be permitted to fertilize one another after their new fashion. In fact, when a blossom which has once depended upon insects for its fertilization is driven by circumstances to depend upon the wind, it seems to derive a positive advantage from losing all those attractive features by which its ancestors formerly allured the eyes of bees or beetles.

Here, again, on the roadside is a bit of plantain. Everybody knows its flat rosette of green leaves and its tall spike of grass-like blossom, with long stamens hanging out to catch the breeze. Now plantain is a case exactly analogous to dog's mercury. It is an example of a degraded blossom. Once upon a time it was a sort of distant cousin to the veronica, that pretty sky-blue speedwell which abounds among the meadows in June and July. But these particular speedwells gave up devoting themselves to insects and became adapted for fertilization by the wind instead. So you must look close at them to see at all that the flowering spike is made up of a hundred separate little four-rayed blossoms, whose pale and faded petals are

tucked away out of sight flat against the stem. Yet their shape and arrangement distinctly recall the beautiful veronica, and leave one in little doubt as to the origin of the plant. At the same time a curious device has sprung up which answers just the same purpose as the separation of the male and female flowers on the dog's mercury. Each plantain blossom has both stamens and pistils, but the pistils come to maturity first, and are fertilized by pollen blown to them from some neighboring spike. Their feathery plumes are admirably adapted for catching and utilizing any stray golden grain which happens to pass that way. After the pistils have faded, the stamens ripen, and hang out at the end of long waving filaments, so as to discharge all their pollen with effect. On each spike of blossoms the lower flowerets open first ; and so, if you pick a half-blown spike, you will see that all the stamens are ripe below, and all the pistils above. Were the opposite arrangement to occur, the pollen would fall from the stamens to the lower flowers of the same stalk ; but as the pistils below have always been fertilized and withered before the stamens ripen, there is no chance of any such accident and its consequent evil results. Thus one can see clearly that the plantain has become wholly adapted to wind - fertilization, and as a natural effect has all but lost its bright-colored corolla.

Common groundsel is also a case of the same kind ; but here the degradation has not gone nearly so far. I venture to conjecture, therefore, that groundsel has been embarked for a shorter time upon its downward course. For evolution is not, as most people seem to fancy, a thing which used once to take place ; it is a process taking place around us every day, and it must necessarily continue to take place to the end of all time. By family the groundsel is a daisy ; but it has acquired the strange and somewhat abnormal habit of self-fertilization, which in all probability will ultimately lead to its total extinction. Hence it does not need the assistance of insects ; and it has accordingly never developed or else got rid of the bright outer ray-florets which may once have attracted them. Its tiny bell-shaped blossoms still retain their dwarf yellow corollas ; but they are almost hidden by the green cup-like investment of the flower-head, and they are not conspicuous enough to arrest the attention of the passing flies. Here, then, we have an example of a plant just beginning to start on the retrograde path already traversed by the plantain and the spurges. If we could meet prophetically with a groundsel of some remote future century, I have little doubt we should find its bell-shaped petals as completely degraded as those of the plantain in our own day.

The general principle which these cases illustrate is that when flowers have always been fertilized by the wind, they never have brilliant corollas ; when they acquire the habit of impregnating their kind by the intervention of insects, they almost always acquire at the same time alluring colors, perfumes, and honey ; and when they have once been so impregnated, and then revert once more to wind-fertilization, or become self-fertilizers, they generally retain some symptoms of their earlier habits, in the presence of dwarfed and useless petals, sometimes green, or if not green at least devoid of their former attractive coloring. Thus every plant bears upon its very face the history of its whole previous development.

XV.

BUTTERFLY PSYCHOLOGY.

A small red - and - black butterfly poises statuesque above the purple blossom of this tall field-thistle. With its long sucker it probes industriously floret after floret of the crowded head, and extracts from each its wee drop of buried nectar. As it stands just at present, the dull outer sides of its four wings are alone displayed, so that it does not form a conspicuous mark for passing birds ; but when it has drunk up the last drop of honey from the thistle flower, and flits joyously away to seek another purple mass of the same

sort, it will open its red-spotted vans in the sunlight, and will then show itself off as one among the prettiest of our native insects. Each thistle-head consists of some two hundred separate little bell-shaped blossoms, crowded together for the sake of conspicuousness into a single group, just as the blossoms of the lilac or the syringa are crowded into larger though less dense clusters; and, as each separate floret has a nectary of its own, the bee or butterfly who lights upon the compound flower-group can busy himself for a minute or two in getting at the various drops of honey without the necessity for any further change of position than that of revolving upon his own axis. Hence these composite flowers are great favorites with all insects whose suckers are long enough to reach the bottom of their slender tubes.

The butterfly's view of life is doubtless on the whole a cheerful one. Yet his existence must be something so nearly mechanical that we probably overrate the amount of enjoyment which he derives from flitting about so airily among the flowers, and passing his days in the unbroken amusement of sucking liquid honey. Subjectively viewed, the butterfly is not a high order of insect; his nervous system does not show that provision for comparatively spontaneous thought and action which we find in the more intelligent orders, like the flies, bees, ants, and wasps. His nerves are all frittered away in little separate ganglia distributed among the various segments of his body, instead of being governed by a single great central organ, or brain, whose business it always is to correlate and co-ordinate complex external impressions. This shows that the butterfly's movements are almost all automatic, or simply dependent upon immediate external stimulants: he has not even that small capacity for deliberation and spontaneous initiative which belongs to his relation the bee. The freedom of the will is nothing to him, or extends at best to the amount claimed on behalf of Buridan's ass: he can just choose which of two equidistant flowers shall first have the benefit of his attention, and nothing else. Whatever view we take on the abstract metaphysical question, it is at least certain that the higher animals can do much more than this. Their brain is able to correlate a vast number of external impressions, and to bring them under the influence of endless ideas or experiences, so as finally to evolve conduct which differs very widely with different circumstances and different characters. Even though it be true, as determinists believe (and I reckon myself among them), that such conduct is the necessary result of a given character and given circumstances — or, if you will, of a particular set of nervous structures and a particular set of external stimuli—yet we all know that it is capable of varying so indefinitely, owing to the complexity of the structures, as to be practically incalculable. But it is not so with the butterfly. His whole life is cut out for him beforehand; his nervous connections are so simple, and correspond so directly with external stimuli, that we can almost predict with certainty what line of action he will pursue under any given circumstances. He is, as it were, but a piece of half-conscious mechanism, answering immediately to impulses from without, just as the thermometer answers to variations of temperature, and as the telegraphic indicator answers to each making and breaking of the electric current.

In early life the future butterfly emerges from the egg as a caterpillar. At once his many legs begin to move, and the caterpillar moves forward by their motion. But the mechanism which set them moving was the nervous system, with its ganglia working the separate legs of each segment. This movement is probably quite as automatic as the act of sucking in the new-born infant. The caterpillar walks, it knows not why, but simply because it has to walk. When it reaches a fit place for feeding, which differs according to the nature of the particular larva, it feeds automatically. Certain special external stimulants of sight, smell, or touch set up the appropriate actions in the mandibles, just as contact of the lips

with an external body sets up sucking in the infant. All these movements depend upon what we call instinct—that is to say, organic habits registered in the nervous system of the race. They have arisen by natural selection alone, because those insects which duly performed them survived, and those which did not duly perform them died out. After a considerable span of life spent in feeding and walking about in search of more food, the caterpillar one day found itself compelled by an inner monitor to alter its habits. Why, it knew not; but, just as a tired child sinks to sleep, the gorged and full-fed caterpillar sank peacefully into a dormant state. Then its tissues melted one by one into a kind of organic pap, and its outer skin hardened into a chrysalis. Within that solid case new limbs and organs began to grow by hereditary impulses. At the same time the form of the nervous system altered, to suit the higher and freer life for which the insect was unconsciously preparing itself. Fewer and smaller ganglia now appeared in the tail segments (since no legs would any longer be needed there), while more important ones sprang up to govern the motions of the four wings. But it was in the head that the greatest changes took place. There, a rudimentary brain made its appearance, with large optic centres, answering to the far more perfect and important eyes of the future butterfly. For the flying insect will have to steer its way through open space, instead of creeping over leaves and stones; and it will have to suck the honey of flowers, as well as to choose its fitting mate, all of which demands from it higher and keener senses than those of the purblind caterpillar. At length one day the chrysalis bursts asunder, and the insect emerges to view on a summer morning as a full-fledged and beautiful butterfly.

For a minute or two it stands and waits till the air it breathes has filled out its wings, and till the warmth and sunlight have given it strength. For the wings are by origin a part of the breathing apparatus, and they require to be plimmed by the air before the insect can take to flight. Then, as it grows more accustomed to its new life, the hereditary impulse causes it to spread its vans abroad, and it flies. Soon a flower catches its eye, and the bright mass of color attracts it irresistibly, as the candle-light attracts the eye of a child a few weeks old. It sets off toward the patch of red or yellow, probably not knowing beforehand that this is the visible symbol of food for it, but merely guided by the blind habit of its race, imprinted with binding force in the very constitution of its body. Thus the moths, which fly by night and visit only white flowers whose corollas still shine out in the twilight, are so irresistibly led on by the external stimulus of light from a candle falling upon their eyes that they cannot choose but move their wings rapidly in that direction; and though singed and blinded twice or three times by the flame, must still wheel and eddy into it, till at last they perish in the scorching blaze. Their instincts, or, to put it more clearly, their simple nervous mechanism, though admirably adapted to their natural circumstances, cannot be equally adapted to such artificial objects as wax candles. The butterfly in like manner is attracted automatically by the color of his proper flowers, and settling upon them, sucks up their honey instinctively. But feeding is not now his only object in life: he has to find and pair with a suitable mate. That, indeed, is the great end of his winged existence. Here, again, his simple nervous system stands him in good stead. The picture of his kind is, as it were, imprinted on his little brain, and he knows his own mates the moment he sees them, just as intuitively as he knows the flowers upon which he must feed. Now we see the reason for the butterfly's large optic centres: they have to guide it in all its movements. In like manner, and by a like mechanism, the female butterfly or moth selects the right spot for laying her eggs, which of course depends entirely upon the nature of the young caterpillars' proper food. Each great group of insects has its own habits in this respect, may-flies laying their eggs on the water, many

beetles on wood, flies on decaying animal matter, and butterflies mostly on special plants. Thus throughout its whole life the butterfly's activity is entirely governed by a rigid law, registered and fixed forever in the constitution of its ganglia and motor nerves. Certain definite objects outside it invariably produce certain definite movements on the insect's part. No doubt it is vaguely conscious of all that it does ; no doubt it derives a faint pleasure from due exercise of all its vital functions, and a faint pain when they are injured or thwarted ; but on the whole its range of action is narrowed and bounded by its hereditary instincts and their nervous correlatives. It may light on one flower rather than another ; it may choose a fresher and brighter mate rather than a battered and dingy one ; but its little subjectivity is a mere shadow compared with ours, and it hardly deserves to be considered as more than a semi-conscious automatic machine.

XVI.

BUTTERFLY ÆSTHETICS.

The other day, when I was watching that little red-spotted butterfly whose psychology I found so interesting, I hardly took enough account, perhaps, of the insect's own subjective feelings of pleasure and pain. The first great point to understand about these minute creatures is that they are, after all, mainly pieces of automatic mechanism : the second great point is to understand that they are probably something more than that as well. To-day I have found another exactly similar butterfly, and I am going to work out with myself the other half of the problem about him. Granted that the insect is, viewed intellectually, a cunning bit of nervous machinery, may it not be true at the same time that he is, viewed emotionally, a faint copy of ourselves ?

Here he stands on a purple thistle again, true, as usual, to the plant on which I last found him. There can be no doubt that he distinguishes one color from another, for you can artificially attract him by putting a piece of purple paper on a green leaf, just as the flower naturally attracts him with its native hue. Numerous observations and experiments have proved with all but absolute certainty that his discrimination of color is essentially identical with our own ; and I think, if we run our eye up and down nature, observing how universally all animals are attracted by pure and bright colors, we can hardly doubt that he appreciates and admires color as well as discriminates it. Mr. Darwin certainly judges that butterflies can show an æsthetic preference of the sort, for he sets down their own lovely hues to the constant sexual selection of the handsomest mates. We must not, however, take too human a measure of their capacities in this respect. It is sufficient to believe that the insect derives some direct enjoyment from the stimulation of pure color, and is hereditarily attracted by it wherever it may show itself. This pleasure draws it on, on the one hand, toward the gay flowers which form its natural food ; and, on the other hand, toward its own brilliant mates. Imprinted on its nervous system is a certain blank form answering to its own specific type ; and when the object corresponding to this blank form occurs in its neighborhood, the insect blindly obeys its hereditary instinct. But out of two or three such possible mates it naturally selects that which is most brightly spotted, and in other ways most perfectly fulfils the specific ideal. We need not suppose that the insect is conscious of making a selection or of the reasons which guide it in its choice : it is enough to believe that it follows the strongest stimulus, just as the child picks out the biggest and reddest apple from a row of ten. Yet such unconscious selections, made from time to time in generation after generation, have sufficed to produce at last all the beautiful spots and metallic eyelets of our loveliest English or tropical butterflies. Insects always accustomed to exercising their color-sense upon flowers and mates, may easily acquire a high standard of taste in that direction, while still remaining comparatively in a low

stage as regards their intellectual condition. But the fact I wish especially to emphasize is this—that the flowers produced by the color-sense of butterflies and their allies are just those objects which we ourselves consider most lovely in nature ; and that the marks and shades upon their own wings, produced by the long selective action of their mates, are just the things which we ourselves consider most beautiful in the animal world. In this respect, then, there seems to be a close community of taste and feeling between the butterfly and ourselves.

Let me note, too, just in passing, that while the upper half of the butterfly's wing is generally beautiful in color, so as to attract his fastidious mate, the under half, displayed while he is at rest, is almost always dull, and often resembles the plant upon which he habitually alights. The first set of colors is obviously due to sexual selection, and has for its object the making an effective courtship ; but the second set is obviously due to natural selection, and has been produced by the fact that all those insects whose bright colors show through too vividly when they are at rest fall a prey to birds or other enemies, leaving only the best protected to continue the life of the species.

But sight is not the only important sense to the butterfly. He is largely moved and guided by smell as well. Both bees and butterflies seem largely to select the flowers they visit by means of smell, though color also aids them greatly. When we remember that in ants scent alone does duty instead of eyes, ears, or any other sense, it would hardly be possible to doubt that other allied insects possessed the same faculty in a high degree ; and, as Dr. Bastian says, there seems good reason for believing that all the higher insects are guided almost as much by smell as by sight. Now it is noteworthy that most of those flowers which lay themselves out to attract bees and butterflies are not only colored but sweetly scented ; and it is to this cause that we owe the perfumes of the rose, the lily-of-the-valley, the heliotrope, the jasmine, the violet, and the stephanotis. Night-flowering plants, which depend entirely for their fertilization upon moths, are almost always white, and have usually very powerful perfumes. Is it not a striking fact that these various scents are exactly those which human beings most admire, and which they artificially extract for essences ? Here, again, we see that the æsthetic tastes of butterflies and men decidedly agree ; and that the thyme or lavender whose perfume pleases the bee is the very thing which we ourselves choose to sweeten our rooms.

Finally, if we look at the sense of taste, we find an equally curious agreement between men and insects ; for the honey which is stored by the flower for the bee and by the bee for its own use, is stolen and eaten up by man instead. Hence, when I consider the general continuity of nervous structure throughout the whole animal race, and the exact similarity of the stimulus in each instance, I can hardly doubt that the butterfly really enjoys life somewhat as we enjoy it, though far less vividly. I cannot but think that he finds honey sweet, and perfumes pleasant, and color attractive ; that he feels a lightsome gladness as he flits in the sunshine from flower to flower, and that he knows a faint thrill of pleasure at the sight of his chosen mate. Still more is this belief forced upon me when I recollect that, so far as I can judge, throughout the whole animal world, save only in a few aberrant types, sugar is sweet to taste, and thyme to smell, and song to hear, and sunshine to bask in. Therefore, on the whole, while I admit that the butterfly is mainly an animated puppet, I must qualify my opinion by adding that it is a puppet which, after its vague little fashion, thinks and feels very much as we do.

XVII.

THE ORIGIN OF WALNUTS.

Mr. Darwin has devoted no small portion of his valuable life to tracing, in two bulky volumes, the Descent of Man. Yet I suppose it is probable that

in our narrow anthropinism we should have refused to listen to him had he given us two volumes instead on the Descent of Walnuts. Viewed as a question merely of biological science, the one subject is just as important as the other. But the old Greek doctrine that "man is the measure of all things" is strong in us still. We form for ourselves a sort of pre-Copernican universe, in which the world occupies the central point of space, and man occupies the central point of the world. What touches man interests us deeply: what concerns him but slightly we pass over as of no consequence. Nevertheless, even the origin and development of walnuts is a subject upon which we may profitably reflect, not wholly without gratification and interest.

This kiln-dried walnut on my plate, which has suggested such abstract cogitations to my mind, is shown by its very name to be a foreign production; for the word contains the same root as Wales and Welsh, the old Teutonic name for men of a different race, which the Germans still apply to the Italians, and we ourselves to the last relics of the old Keltic population in Southern Britain. It means "the foreign nut," and it comes for the most part from the south of Europe. As a nut, it represents a very different type of fruit from the strawberry and raspberry, with their bright colors, sweet juices, and nutritious pulp. Those fruits which alone bear the name in common parlance are attractive in their object; the nuts are deterrent. An orange or a plum is brightly tinted with hues which contrast strongly with the surrounding foliage; its pleasant taste and soft pulp all advertise it for the notice of birds or monkeys, as a means for assisting in the dispersion of its seed. But a nut, on the contrary, is a fruit whose actual seed contains an abundance of oils and other pleasant food-stuffs, which must be carefully guarded against the depredations of possible foes. In the plum or the orange we do not eat the seed itself: we only eat the surrounding pulp. But in the walnut the part which we utilize is the embryo plant itself; and so the walnut's great object in life is to avoid being eaten. Accordingly, that part of the fruit which in the plum is stored with sweet juices is, in the walnut, filled with a bitter and very nauseous essence. We seldom see this bitter covering in our over-civilized life, because it is, of course, removed before the nuts come to table. The walnut has but a thin shell, and is poorly protected in comparison with some of its relations, such as the American butternut, which can only be cracked by a sharp blow from a hammer—or even the hickory, whose hard covering has done more to destroy the teeth of New Englanders than all other causes put together, and New England teeth are universally admitted to be the very worst in the world. Now, all nuts have to guard against squirrels and birds; and therefore their peculiarities are exactly opposite to those of succulent fruits. Instead of attracting attention by being brightly colored, they are invariably green like the leaves while they remain on the tree, and brown or dusky like the soil when they fall upon the ground beneath; instead of being inclosed in sweet coats, they are provided with bitter, acrid, or stinging husks; and, instead of being soft in texture, they are surrounded by hard shells, like the cocoanut, or have a perfectly solid kernel, like the vegetable ivory.

The origin of nuts is thus exactly the reverse side of the origin of fruits. Certain seeds, richly stored with oils and starches for aiding the growth of the young plant, are exposed to the attacks of squirrels, monkeys, parrots, and other arboreal animals. The greater part of them are eaten and completely destroyed by these their enemies, and so never hand down their peculiarities to any descendants. But all fruits vary a little in sweetness and bitterness, pulpy or stringy tendencies. Thus a few among them happen to be protected from destruction by their originally accidental possession of a bitter husk, a hard shell, or a few awkward spines and bristles. These the monkeys and squirrels reject; and they alone survive as the parents of future genera-

tions. The more persistent and the hungrier their foes become, the less will a small degree of bitterness or hardness serve to protect them. Hence, from generation to generation, the bitterness and the hardness will go on increasing, because only those nuts which are the nastiest and the most difficult to crack will escape destruction from the teeth or bills of the growing and pressing population of rodents and birds. The nut which best survives on the average is that which is least conspicuous in color, has a rind of the most objectionable taste, and is inclosed in the most solid shell. But the extent to which such precautions become necessary will depend much upon the particular animals to whose attacks the nuts of each country are exposed. The European walnut has only to defy a few small woodland animals, who are sufficiently deterred by its acrid husk ; the American butternut has to withstand the long teeth of much more formidable forestine rodents, whom it sets at naught with its stony and wrinkled shell ; and the tropical cocoas and Brazil nuts have to escape the monkey, who pounds them with stones, or flings them with all his might from the tree-top so as to smash them in their fall against the ground below.

Our own hazelnut supplies an excellent illustration of the general tactics adopted by the nuts at large. The little red tufted blossoms which everybody knows so well in early spring are each surrounded by a bunch of three bracts ; and as the nut grows bigger, these bracts form a green leaf-like covering, which causes it to look very much like the ordinary foliage of the hazel-tree. Besides, they are thickly set with small prickly hairs, which are extremely annoying to the fingers, and must prove far more unpleasant to the delicate lips and noses of lower animals. Just at present the nuts have reached this stage in our copses ; but as soon as autumn sets in, and the seeds are ripe, they will turn brown, fall out of their withered investment, and easily escape notice on the soil beneath, where the dead leaves will soon cover them up in a mass of shrivelled brown, indistinguishable in shade from the nuts themselves. Take, as an example of the more carefully protected tropical kinds, the cocoanut. Growing on a very tall palm-tree, it has to fall a considerable distance toward the earth ; and so it is wrapped round in a mass of loose knitted fibre, which breaks the fall just as a lot of soft wool would do. Then, being a large nut, fully stored with an abundance of meat, it offers special attractions to animals, and consequently requires special means of defence. Accordingly its shell is extravagantly thick, only one small soft spot being left at the blunter end, through which the young plant may push its head. Once upon a time, to be sure, the cocoanut contained three kernels, and had three such soft spots or holes ; but now two of them are aborted, and the two holes remain only in the form of hard scars. The Brazil-nut is even a better illustration. Probably few people know that the irregular angular nuts which appear at dessert by that name are originally contained inside a single round shell where they fit tightly together, and acquire their queer indefinite shapes by mutual pressure. So the South American monkey has first to crack the thick external common shell against a stone or otherwise ; and if he is successful in this process, he must afterward break the separate sharp-edged inner nuts with his teeth—a performance which is always painful and often ineffectual.

Yet it is curious that nuts and fruits are really produced by the very slightest variations on a common type, so much so that the technical botanist does not recognize the popular distinction between them at all. In his eyes, the walnut and the cocoanut are not nuts, but "drupaceous fruits," just like the plum and the cherry. All four alike contain a kernel within, a hard shell outside it, and a fibrous mass outside that again, bounded by a thin external layer. Only, while in the plum and cherry this fibrous mass becomes succulent and fills with sugary juice, in the walnut its juice is bitter, and in the cocoanut it has no juice at all, but re-

mains a mere matted layer of dry fibres. And while the thin external skin becomes purple in the plum and red in the cherry as the fruits ripen, it remains green and brown in the walnut and cocoanut all their time. Nevertheless, Darwinism shows us both here and elsewhere that the popular distinction answers to a real difference of origin and function. When a seed-vessel, whatever its botanical structure, survives by dint of attracting animals, it always acquires a bright-colored envelope and a sweet pulp ; while it usually possesses a hard seed-shell, and often infuses bitter essences into its kernel. On the other hand, when a seed-vessel survives by escaping the notice of animals, it generally has a sweet and pleasant kernel, which it protects by a hard shell and an inconspicuous and nauseous envelope. If the kernel itself is bitter, as with the horse-chestnut, the need for disguise and external protection is much lessened. But the best illustration of all is seen in the West Indian cashew-nut, which is what Alice in Wonderland would have called a portmanteau seed-vessel—a fruit and a nut rolled into one. In this curious case, the stalk swells out into a bright-colored and juicy mass, looking something like a pear, but of course containing no seeds ; while the nut grows out from its end, secured from intrusion by a covering with a pungent juice, which burns and blisters the skin at a touch. No animal except man can ever successfully tackle the cashew-nut itself ; but by eating the pear-like stalk other animals ultimately aid in distributing the seed. The cashew thus vicariously sacrifices its fruit-stem for the sake of preserving its nut.

All nature is a continuous game of cross-purposes. Animals perpetually outwit plants, and plants in return once more outwit animals. Or, to drop the metaphor, those animals alone survive which manage to get a living in spite of the protections adopted by plants ; and those plants alone survive whose peculiarities happen successfully to defy the attack of animals. There you have the Darwinian Iliad in a nutshell.

XVIII.

A PRETTY LAND-SHELL.

The heavy rains which have done so much harm to the standing corn have at least had the effect of making the country look greener and lovelier than I have seen it look for many seasons. There is now a fresh verdure about the upland pastures and pine woods which almost reminds one of the deep valleys of the Bernese Oberland in early spring. Last year's continuous wet weather gave the trees and grass a miserable draggled appearance ; but this summer's rain, coming after a dry spring, has brought out all the foliage in unwonted luxuriance ; and everybody (except the British farmer) agrees that we have never seen the country look more beautiful. Though the year is now so far advanced, the trees are still as green as in springtide ; and the meadows, with their rich aftermath springing up apace, look almost as lush and fresh as they did in early June. Londoners who get away to the country or the seaside this month will enjoy an unexpected treat in seeing the fields as they ought to be seen a couple of months sooner in the season.

Here, on the edge of the down, where I have come up to get a good blowing from the clear south-west breeze, I have just sat down to rest myself a while and to admire the view, and have reverted for a moment to my old habit of snail-hunting. Years ago, when evolution was an infant—an infant much troubled by the complaints inseparable from infancy, but still a sturdy and vigorous child, destined to outlive and outgrow its early attacks—I used to collect slugs and snails, from an evolutionist standpoint, and put their remains into a cabinet ; and to this day I seldom go out for a walk without a few pill-boxes in my pocket, in case I should happen to hit upon any remarkable specimen. Now here in the tall moss which straggles over an old heap of stones I have this moment lighted upon a beautifully marked shell of our prettiest English snail. How beautiful it is I could hardly make you believe, unless I had you here and could show

it to you; for most people only know the two or three ugly brown or banded snails that prey upon their cabbages and lettuces, and have no notion of the lovely shells to be found by hunting among English copses and under the dead leaves of Scotch hill-sides. This cyclostoma, however—I *must* trouble you with a Latin name for once—is so remarkably pretty, with its graceful elongated spiral whorls, and its delicately chiselled fretwork tracery, that even naturalists (who have perhaps, on the whole, less sense of beauty than any class of men I know) have recognized its loveliness by giving it the specific epithet of *elegans*. It is big enough for anybody to notice it, being about the size of a periwinkle; and its exquisite stippled chasing is strongly marked enough to be perfectly visible to the naked eye. But besides its beauty, the cyclostoma has a strong claim upon our attention because of its curious history.

Long ago, in the infantile days of evolutionism, I often wondered why people made collections on such an irrational plan. They always try to get what they call the most typical specimens, and reject all those which are doubtful or intermediate. Hence the dogma of the fixity of species becomes all the more firmly settled in their minds, because they never attend to the existing links which still so largely bridge over the artificial gaps created by our nomenclature between kind and kind. I went to work on the opposite plan, collecting all those aberrant individuals which most diverged from the specific type. In this way I managed to make some series so continuous that one might pass over specimens of three or four different kinds, arranged in rows, without ever being able to say quite clearly, by the eye alone, where one group ended and the next group began. Among the snails such an arrangement is peculiarly easy; for some of the species are very indefinite, and the varieties are numerous under each species. Nothing can give one so good a notion of the plasticity of organic forms as such a method. The endless varieties and intermediate links which exist among dogs is the nearest example to it with which ordinary observers are familiar.

But the cyclostoma is a snail which introduces one to still deeper questions. It belongs in all our scientific classifications to the group of lung-breathing mollusks, like the common garden snail. Yet it has one remarkable peculiarity: it possesses an operculum, or door to its shell, like that of the periwinkle. This operculum represents among the univalves the under-shell of the oyster or other bivalves; but it has completely disappeared in most land and fresh-water snails, as well as among many marine species. The fact of its occurrence in the cyclostoma would thus be quite inexplicable if we were compelled to regard it as a descendant of the other lung-breathing mollusks. So far as I know, all naturalists have till lately always so regarded it; but there can be very little doubt, with the new light cast upon the question by Darwinism, that they are wrong. There exists in all our ponds and rivers another snail, not breathing by means of lungs, but provided with gills, known as paludina. This paludina has a door to its shell, like the cyclostoma; and so, indeed, have all its allies. Now, strange as it sounds to say so, it is pretty certain that we must really class this lung-breathing cyclostoma among the gill-breathers, because of its close resemblance to the paludina. It is, in fact, one of these gill-breathing pond-snails which has taken to living on dry land, and so has acquired the habit of producing lungs. All molluscan lungs are very simple: they consist merely of a small sac or hollow behind the head, lined with blood-vessels; and every now and then the snail opens this sac, allowing the air to get in and out by natural change, exactly as when we air a room by opening the windows. So primitive a mechanism as this could be easily acquired by any soft-bodied animal like a snail. Besides, we have many intermediate links between the pond-snails and my cyclostoma here. There are some species which live in moist moss, or the beds of trickling

streams. There are others which go farther from the water, and spend their days in damp grass. And there are yet others which have taken to a wholly terrestrial existence in woods or meadows and under heaps of stones. All of them agree with the pond-snails in having an operculum, and so differ from the ordinary land and river-snails, the mouths of whose shells are quite unprotected. Thus land-snails have two separate origins—one large group (including the garden-snail) being derived from the common fresh-water mollusks, while another much smaller group (including the cyclostoma) is derived from the operculated pond-snails.

How is it, then, that naturalists had so long overlooked this distinction? Simply because their artificial classification is based entirely upon the nature of the breathing apparatus. But, as Mr. Wallace has well pointed out, obvious and important functional differences are of far less value in tracing relationship than insignificant and unimportant structural details. Any water-snail may have to take to a terrestrial life if the ponds in which it lives are liable to dry up during warm weather. Those individuals alone will then survive which display a tendency to oxygenize their blood by some rudimentary form of lung. Hence the possession of lungs is not the mark of a real genealogical class, but a mere necessary result of a terrestrial existence. On the other hand, the possession of an operculum, unimportant as it may be to the life of the animal, is a good test of relationship by descent. All snails which take to living on land, whatever their original form, will acquire lungs; but an operculated snail will retain its operculum, and so bear witness to its ancestry; while a snail which is not operculated will of course show no tendency to develop such a structure, and so will equally give a true testimony as to its origin. In short, the less functionally useful any organ is, the higher is its value as a gauge of its owner's pedigree, like a Bourbon nose or an Austrian lip.

XIX.

DOGS AND MASTERS.

PROBABLY the most forlorn and abject creature to be seen on the face of the earth is a masterless dog. Slouching and slinking along, cringing to every human being it chances to meet, running away with its tail between its legs from smaller dogs whom under other circumstances it would accost with a gruff who-the-dickens-are-you sort of growl—it forms the very picture of utter humiliation and self-abasement. Grip and I have just come across such a lost specimen of stray doghood, trying to find his way back to his home across the fields—I fancy he belongs to a travelling show which left the village yesterday—and it is quite refreshing to watch the air of superior wisdom and calm but mute compassionateness with which Grip casts his eye sidelong upon that wretched masterless vagrant, and passes him by without even a nod. He looks up to me complacently as he trots along by my side, and seems to say with his eye, "Poor fellow! he's lost his master, you know — careless dog that he is!" I believe the lesson has had a good moral effect upon Grip's own conduct, too; for he has now spent ten whole minutes well within my sight, and has resisted the most tempting solicitations to ratting and rabbiting held out by half a dozen holes and burrows in the hedge-wall as we go along.

This total dependence of dogs upon a master is a very interesting example of the growth of inherited instincts. The original dog, who was a wolf or something very like it, could not have had any such artificial feeling. He was an independent, self-reliant animal, quite well able to look after himself on the boundless plains of Central Europe or High Asia. But at least as early as the days of the Danish shell-mounds, perhaps thousands of years earlier, man had learned to tame the dog and to employ him as a friend or servant for his own purposes. Those dogs which best served the ends of man were preserved and increased; those which fol-

lowed too much their own original instincts were destroyed or at least discouraged. The savage hunter would be very apt to fling his stone axe at the skull of a hound which tried to eat the game he had brought down with his flint-tipped arrow, instead of retrieving it : he would be most likely to keep carefully and feed well on the refuse of his own meals the hound which aided him most in surprising, killing, and securing his quarry. Thus there sprang up between man and the dog a mutual and ever-increasing sympathy which on the part of the dependent creature has at last become organized into an inherited instinct. If we could only thread the labyrinth of a dog's brain, we should find somewhere in it a group of correlated nerve-connections answering to this universal habit of his race ; and the group in question would be quite without any analogous mechanism in the brain of the ancestral wolf. As truly as the wing of the bird is adapted to its congenital instinct of flying, as truly as the nervous system of the bee is adapted to its congenital instinct of honeycomb building, just so truly is the brain of the dog adapted to its now congenital instinct of following and obeying a master. The habit of attaching itself to a particular human being is nowadays ingrained in the nerves of the modern dog just as really, though not quite so deeply, as the habit of running or biting is ingrained in its bones and muscles. Every dog is born into the world with a certain inherited structure of limbs, sense-organs, and brain : and this inherited structure governs all its future actions, both bodily and mental. It seeks a master because it is endowed with master-seeking brain organs ; it is dissatisfied until it finds one, because its native functions can have free play in no other way. Among a few dogs, like those of Constantinople, the instinct may have died out by disuse, as the eyes of cave animals have atrophied for want of light ; but when a dog has once been brought up from puppyhood under a master, the instinct is fully and freely developed, and the masterless condition is thenceforth for him a thwarting and disappointing of all his natural feelings and affections.

Not only have dogs as a class acquired a special instinct with regard to humanity generally, but particular breeds of dogs have acquired particular instincts with regard to certain individual acts. Nobody doubts that the muscles of a greyhound are specially correlated to the acts of running and leaping ; or that the muscles of a bulldog are specially correlated to the act of fighting. The whole external form of these creatures has been modified by man's selective action for a deliberate purpose : we breed, as we say, from the dog with the best points. But besides being able to modify the visible and outer structure of the animal, we are also able to modify, by indirect indications, the hidden and inner structure of the brain. We choose the best ratter among our terriers, the best pointer, retriever, or setter among other breeds, to become the parents of our future stock. We thus half unconsciously select particular types of nervous system in preference to others. Once upon a time we used even to rear a race of dogs with a strange instinct for turning the spit in our kitchens ; and to this day the Cubans rear bloodhounds with a natural taste for hunting down the trail of runaway negroes. Now, everybody knows that you cannot teach one sort of dog the kind of tricks which come by instinct to a different sort. No amount of instruction will induce a well-bred terrier to retrieve your handkerchief : he insists upon worrying it instead. So no amount of instruction will induce a well-bred retriever to worry a rat : he brings it gingerly to your feet, as if it was a dead partridge. The reason is obvious, because no one would breed from a retriever which worried or from a terrier which treated its natural prey as if it were a stick. Thus the brain of each kind is hereditarily supplied with certain nervous connections wanting in the brain of other kinds. We need no more doubt the reality of the material distinction in the brain than we need doubt it in the limbs and jaws of the

greyhound and the bulldog. Those who have watched closely the different races of men can hardly hesitate to believe that something analogous exists in our own case. While the highest types are, as Mr. Herbert Spencer well puts it, to some extent "organically moral" and structurally intelligent, the lowest types are congenitally deficient. A European child learns to read almost by nature (for Dogberry was essentially right after all), while a Negro child learns to read by painful personal experience. And savages brought to Europe and "civilized" for years often return at last with joy to their native home, cast off their clothes and their outer veneering, and take once more to the only life for which their nervous organization naturally fits them. "What is bred in the bone," says the wise old proverb, "will out in the blood."

XX.

BLACKCOCK.

Just at the present moment the poor black grouse are generally having a hot time of it. After their quiet spring and summer they suddenly find their heath-clad wastes invaded by a strange epidemic of men, dogs, and hideous shooting implements ; and being as yet but young and inexperienced, they are falling victims by the thousand to their youthful habit of clinging closely for protection to the treacherous reed-beds. A little later in the season, those of them that survive will have learned more wary ways : they will pack among the juniper thickets, and become as cautious on the approach of perfidious man as their cunning cousins, the red grouse of the Scottish moors. But so far youthful innocence prevails ; no sentinels as yet are set to watch for the distant gleam of metal, and no foreshadowing of man's evil intent disturbs their minds as they feed in fancied security upon the dry seeds of the marsh plants in their favorite sedges.

The great families of the pheasants and partridges, in which the blackcock must be included, may be roughly divided into two main divisions so far as regards their appearance and general habits. The first class consists of splendidly colored and conspicuous birds, such as the peacock, the golden pheasant, and the tragopan ; and these are, almost without exception, originally jungle-birds of tropical or sub-tropical lands, though a few of them have been acclimatized or domesticated in temperate countries. They live in regions where they have few natural enemies, and where they are little exposed to the attacks of man. Most of them feed more or less upon fruits and bright-colored food-stuffs, and they are probably every one of them polygamous in their habits. Thus we can hardly doubt that the male birds, which alone possess the brilliant plumage of their kind, owe their beauty to the selective preference of their mates ; and that the taste thus displayed has been aroused by their relation to their specially gay and bright natural surroundings. The most lovely species of pheasants are found among the forests of the Himalayas and the Malay Archipelago, with their gorgeous fruits and flowers and their exquisite insects. Even in England our naturalized Oriental pheasants still delight in feeding upon blackberries, sloes, haws, and the pretty fruit of the honeysuckle and the holly ; while our dingier partridges and grouse subsist rather upon heather, grain, and small seeds. Since there must always be originally nearly as many cocks as hens in each brood, it will follow that only the handsomest or most attractive in the polygamous species will succeed in attracting to them a harem ; and as beauty and strength usually go hand in hand, they will also be the conquerors in those battles which are universal with all polygamists in the animal world. Thus we account for the striking and conspicuous difference between the peacock and the peahen, or between the two sexes in the pheasant, the turkey, and the domestic fowl.

On the other hand, the second class consists of those birds which are exposed to the hostility of many wild animals, and more especially of man. These

kinds, typified by the red grouse, partridges, quails, and guinea-fowls, are generally dingy in hue, with a tendency to pepper-and-salt in their plumage; and they usually display very little difference between the sexes, both cocks and hens being colored and feathered much alike. In short, they are protectively designed, while the first class are attractive. Their plumage resembles as nearly as possible the ground on which they sit or the covert in which they skulk. They are thus enabled to escape the notice of their natural enemies, the birds of prey, from whose ravages they suffer far more in a state of nature than from any other cause. We may take the ptarmigans as the most typical example of this class of birds; for in summer their zigzagged black-and-brown attire harmonizes admirably with the patches of faded heath and soil upon the mountain-side, as every sportsman well knows; while in the winter their pure white plumage can scarcely be distinguished from the snow in which they lie huddled and crouching during the colder months. Even in the brilliant species, Mr. Darwin and Mr. Wallace have pointed out that the ornamental colors and crest are never handed down to female descendants when the habits of nesting are such that their mothers would be exposed to danger by their conspicuousness during - incubation. Speaking broadly, only those female birds which build in hollow trees or make covered nests have bright hues at all equal to those of the males. A female bird nesting in the open would be cut off if it showed any tendency to reproduce the brilliant coloring of its male relations.

Now the blackcock occupies to some extent an intermediate position between these two types of pheasant life, though it inclines on the whole to that first described. It is a polygamous bird, and it differs most conspicuously in plumage from its consort, the gray-hen, as may be seen from the very names by which they are each familiarly known. Yet, though the blackcock is handsome enough, and shows evident marks of selective preference on the part of his ancestral hens, this preference has not exerted itself largely in the direction of bright color, and that for two reasons. In the first place the blackcock does not feed upon brilliant food-stuffs, but upon small bog-berries, hard seeds, and young shoots of heather, and it is probable that an æsthetic taste for pure and dazzling hues is almost confined to those creatures which, like butterflies, humming-birds, and parrots, seek their livelihood among beautiful fruits or flowers. In the second place, red, yellow, or orange ornaments would render the blackcock too conspicuous a mark for the hawk, the falcon, or the weapons of man; for we must remember that only those blackcocks survive from year to year and hand down their peculiarities to descendants which succeed in evading the talons of birds of prey or the small-shot of sportsmen. Feeding as they do on the open, they are not protected, like jungle - birds, by the shade of trees. Thus any bird which showed any marked tendency to develop brighter or more conspicuous plumage would almost infallibly fall a victim to one or other of his many foes; and however much his beauty might possibly charm his mates (supposing them for the moment to possess a taste for color), he would have no chance of transmitting it to a future generation. Accordingly, the decoration of the blackcock is confined to glossy plumage and a few ornamental tail-feathers. The gray-hen herself still retains the dull and imitative coloring of the grouse race generally; and as for the cocks, even if a fair percentage of them is annually cut off through their comparative conspicuousness as marks, their loss is less felt than it would be in a monogamous community. Every spring the blackcock hold a sort of assembly or court of love, at which the pairing for the year takes place. The cocks resort to certain open and recognized spots, and there invite the gray-hens by their calls, a little duelling going on meanwhile. During these meetings they show off their beauty with great emulation, after the fashion with which we are all familiar in the case of the

peacock; and when they have gained the approbation of their mates and maimed or driven away their rivals, they retire with their respective families. Unfortunately, like most polygamists, they make bad fathers, leaving the care of their young almost entirely to the hens. According to the veracious account of Artemus Ward, the great Brigham Young himself pathetically descanted upon the difficulty of extending his parental affections to 131 children. The imperious blackcock seems to labor under the same sentimental disadvantage.

XXI.

BINDWEED.

Not the least beautiful among our native wild flowers are many of those which grow, too often unheeded, along the wayside of every country-road. The hedge-bordered highway on which I am walking to-day, to take my letters to the village post, is bordered on either side with such a profusion of color as one may never see equalled during many years' experience of tropical or sub-tropical lands. Jamaica and Ceylon could produce nothing so brilliant as this tangled mass of gorse, and thistle, and St. John's-wort, and centaury, intermingled with the lithe and whitening sprays of half-opened clematis. And here, on the very edge of the road, half smothered in its gray dust, I have picked a pretty little convolvulus blossom, with a fly buried head-foremost in its pink bell; and I am carrying them both along with me as I go, for contemplation and study. For this little flower, the lesser bindweed, is rich in hints as to the strange ways in which Nature decks herself with so much waste loveliness, whose meaning can only be fully read by the eyes of man, the latest comer among her children. The old school of thinkers imagined that beauty was given to flowers and insects for the sake of man alone: it would not, perhaps, be too much to say that, if the new school be right, the beauty is not in the flowers and insects themselves at all, but is read into them by the fancy of the human race. To the butterfly the world is a little beautiful; to the farm-laborer it is only a trifle more beautiful; but to the cultivated man or the artist it is lovely in every cloud and shadow, in every tiny blossom and passing bird.

The outer face of the bindweed, the exterior of the cup, so to speak, is prettily marked with five dark russet-red bands, between which the remainder of the corolla is a pale pinky-white in hue. Nothing could be simpler and prettier than this alternation of dark and light belts; but how is it produced? Merely thus. The convolvulus blossom in the bud is twisted or contorted round and round, part of the cup being folded inside, while the five joints of the corolla are folded outside, much after the fashion of an umbrella when rolled up. And just as the bits of the umbrella which are exposed when it is folded become faded in color, so the bits of the bindweed blossom which are outermost in the bud become more deeply oxidized than the other parts, and acquire a russet-red hue. The belted appearance which thus results is really as accidental, if I may use that unphilosophical expression, as the belted appearance of the old umbrella, or the wrinkles caused by the waves on the sea-sands. The flower happened to be folded so, and got colored, or discolored, accordingly. But when a man comes to look at it, he recognizes in the alternation of colors and the symmetrical arrangement one of those elements of beauty with which he is familiar in the handicraft of his own kind. He reads an intention into this result of natural causes, and personifies Nature as though she worked with an æsthetic design in view, just as a decorative artist works when he similarly alternates colors or arranges symmetrical and radial figures on a cup or other piece of human pottery. The beauty is not in the flower itself; it is in the eye which sees and the brain which recognizes the intellectual order and perfection of the work.

I turn the bindweed blossom mouth upward, and there I see that these rus-

set marks, though paler on the inner surface, still show faintly through the pinky white corolla. This produces an effect not unlike that of a delicate shell cameo, with its dainty gradations of semi-transparent white and interfusing pink. But the inner effect can be no more designed with an eye to beauty than the outer one was; and the very terms in which I think of it clearly show that my sense of its loveliness is largely derived from comparison with human handicraft. A farmer would see in the convolvulus nothing but a useless weed; a cultivated eye sees in it just as much as its nature permits it to see. I look closer, and observe that there are also thin lines running from the circumference to the centre, midway between the dark belts. These lines, which add greatly to the beauty of the flower, by marking it out into zones, are also due to the folding in the bud; they are the inner angles of the folds, just as the dark belts are the overlapping edges of the outer angles. But, in addition to the minor beauty of these little details, there is the general beauty of the cup as a whole, which also calls for explanation. Its shape is as graceful as that of any Greek or Etruscan vase, as swelling and as simply beautiful as any beaker. Can I account for these peculiarities on mere natural grounds as well as for the others? I somehow fancy I can.

The bindweed is descended from some earlier ancestors which had five separate petals, instead of a single fused and circular cup. But in the convolvulus family, as in many others, these five petals have joined into a continuous rim or bowl, and the marks on the blossom where it was folded in the bud still answer to the five petals. In many plants you can see the pointed edges of the former distinct flower-rays as five projections, though their lower parts have coalesced into a bell-shaped or tubular blossom, as in the common harebell. How this comes to pass we can easily understand if we watch an unopened fuchsia; for there the four bright-colored sepals remain joined together till the bud is ready to open, and then split along a line marked out from the very first. In the plastic bud condition it is very easy for parts usually separate so to grow out in union with one another. I do not mean that separate pieces actually grow together, but that pieces which usually grow distinct sometimes grow united from the very first. Now, four or five petals, radially arranged, in themselves produce that kind of symmetry which man, with his intellectual love for order and definite patterns, always finds beautiful. But the symmetry in the flower simply results from the fact that a single whorl of leaves has grown into this particular shape, while the outer and inner whorls have grown into other shapes; and every such whorl always and necessarily presents us with an example of the kind of symmetry which we so much admire. Again, when the petals forming a whorl coalesce, they must, of course, produce a more or less regular circle. If the points of the petals remain as projections, then we get a circle with vandyked edges, as in the lily of the valley; if they do not project, then we get a simple circular rim, as in the bindweed. All the lovely shapes of bell-blossoms are simply due to the natural coalescence of four, five, or six petals; and this coalescence is again due to an increased certainty of fertilization secured for the plant by the better adaptation to insect visits. Similarly, we know that the colors of the corolla have been acquired as a means of rendering the flower conspicuous to the eyes of bees or butterflies; and the hues which so prove attractive to insects are of the same sort which arouse pleasurable stimulation in our own nerves. Thus the whole loveliness of flowers is in the last resort dependent upon all kinds of accidental causes—causes, that is to say, into which the deliberate design of the production of beautiful effects did not enter as a distinct factor. Those parts of nature which are of such a sort as to arouse in us certain feelings we call beautiful; and those parts which are of such a sort as to arouse in us the opposite feelings we call ugly. But the beauty and the ugliness are not

parts of the things; they are merely human modes of regarding some among their attributes. Wherever in nature we find pure color, symmetrical form, and intricate variety of pattern, we imagine to ourselves that nature designs the object to be beautiful. When we trace these peculiarities to their origin, however, we find that each of them owes its occurrence to some special fact in the history of the object; and we are forced to conclude that the notion of intentional design has been read into it by human analogies. All nature is beautiful, and most beautiful for those in whom the sense of beauty is most highly developed; but it is not beautiful at all except to those whose own eyes and emotions are fitted to perceive its beauty.

XXII.

ON CORNISH CLIFFS.

I AM lying on my back in the sunshine, close to the edge of a great broken precipice, beside a clambering Cornish fishing village. In front of me is the sea, bluer than I have seen it since last I lay in like fashion a few months ago on the schistose slopes of the Maurettes at Hyères, and looked away across the plain to the unrippled Mediterranean and the Stœchades of the old Phocæan merchantmen. On either hand rise dark cliffs of hornblende and serpentine, weathered above by wind and rain, and smoothed below by the ceaseless dashing of the winter waves. Up to the limit of the breakers the hard rock is polished like Egyptian syenite; but beyond that point it is fissured by disintegration and richly covered with a dappled coat of gray and yellow lichen. The slow action of the water, always beating against the solid wall of crystalline rock, has eaten out a thousand such little bays all along this coast, each bounded by long headlands, whose points have been worn into fantastic pinnacles, or severed from the main mass as precipitous islets, the favorite resting-place of gulls and cormorants. No grander coast scenery can be found anywhere in the southern half of Great Britain.

Yet when I turn inland I see that all this beauty has been produced by the mere interaction of the sea and the barren moors of the interior. Nothing could be flatter or more desolate than the country whose seaward escarpment gives rise to these romantic coves and pyramidal rocky islets. It stretches away for miles in a level upland waste, only redeemed from complete barrenness by the low straggling bushes of the dwarf furze, whose golden blossom is now interspersed with purple patches of ling or the paler pink flowers of the Cornish heath. Here, then, I can see beauty in nature actually beginning to be. I can trace the origin of all these little bays from small rills which have worn themselves gorge-like valleys through the hard igneous rock, or else from fissures finally giving rise to sea-caves, like the one into which I rowed this morning for my early swim. The waves penetrate for a couple of hundred yards into the bowels of the rock, hemmed in by walls and roof of dark serpentine, with its interlacing veins of green and red bearing witness still to its once molten condition; and at length in most cases they produce a blow-hole at the top, communicating with the open air above, either because the fissure there crops up to the surface, or else through the agency of percolation. At last, the roof falls in; the boulders are carried away by the waves; and we get a long and narrow cove, still bounded on either side by tall cliffs, whose summits the air and rainfall slowly wear away into jagged and exquisite shapes. Yet in all this we see nothing but the natural play of cause and effect; we attribute the beauty of the scene merely to the accidental result of inevitable laws; we feel no necessity for calling in the aid of any underlying æsthetic intention on the part of the sea, or the rock, or the creeping lichen, in order to account for the loveliness which we find in the finished picture. The winds and the waves carved the coast into these varied shapes by force of blind currents working on hidden veins of harder or softer crystal; and we happen to find the result beautiful,

just as we happen to find the inland level, dull, and ugly. The endless variety of the one charms us, while the unbroken monotony of the other wearies and repels us.

Here on the cliff I pick up a pretty fern and a blossoming head of the autumn squill—though so sweet a flower deserves a better name. This fern, too, is lovely in its way, with its branching leaflets and its rich glossy-green hue. Yet it owes its shape just as truly to the balance of external and internal forces acting upon it as it does the Cornish coast-line. How comes it then that in the one case we instinctively regard the beauty as accidental, while in the other we set it down to a deliberate æsthetic intent? I think because, in the first case, we can actually see the forces at work, while in the second they are so minute and so gradual in their action as to escape the notice of all but trained observers. This fern grows in the shape that I see, because its ancestors have been slowly moulded into such a form by the whole group of circumstances directly or indirectly affecting them in all their past life; and the germ of the complex form thus produced was impressed by the parent plant upon the spore from which this individual fern took its birth. Over yonder I see a great dock-leaf; it grows tall and rank above all other plants, and is able to spread itself boldly to the light on every side. It has abundance of sunshine as a motive-power of growth, and abundance of air from which to extract the carbon that it needs. Hence it and all its ancestors have spread their leaves equally on every side, and formed large flat undivided blades. Leaves such as these are common enough; but nobody thinks of calling them pretty. Their want of minute subdivision, their monotonous outline, their dull surface, all make them ugly in our eyes, just as the flatness of the Cornish plain makes it also ugly to us. Where symmetry is slightly marked and variety wanting, as in the cabbage leaf, the mullein, and the burdock, we see little or nothing to admire. On the other hand, ferns generally grow in hedgerows or thickets, where sunlight is much interrupted by other plants, and where air is scanty, most of its carbon being extracted by neighboring plants which leave but little for one another's needs. Hence you may notice that most plants growing under such circumstances have leaves minutely subdivided, so as to catch such stray gleams of sunlight and such floating particles of carbonic acid as happen to pass their way. Look into the next tangled and overgrown hedgerow which you happen to pass, and you will see that almost all its leaves are of this character; and when they are otherwise the anomaly usually admits of an easy explanation. Of course the shapes of plants are mostly due to their normal and usual circumstances, and are comparatively little influenced by the accidental surroundings of individuals; and so when a fern of such a sort happens to grow like this one on the open, it still retains the form impressed upon it by the life of its ancestors. Now, it is the striking combination of symmetry and variety in the fern, together with vivid green coloring, which makes us admire it so much. Not only is the frond as a whole symmetrical, but each frondlet and each division of the frondlet is separately symmetrical as well. This delicate minuteness of workmanship, as we call it, reminds us of similar human products—of fine lace, of delicate tracery, of skilful filigree or engraving. Almost all the green leaves which we admire are noticeable, more or less, for the same effects as in the case of maple, parsley, horse-chestnut, and vine. It is true, mere glossy greenness may, and often does, make up for the want of variety, as we see in the arum, holly, laurel, and hart's-tongue fern; but the leaves which we admire most of all are those which, like maidenhair, are both exquisitely green and delicately designed in shape. So that, in the last resort, the beauty of leaves, like the beauty of coast scenery, is really due to the constant interaction of a vast number of natural laws, not to any distinct æsthetic intention on the part of Nature.

On the other hand, the pretty plus

squill reminds me that semi-conscious æsthetic design in animals has something to do with the production of beauty in nature—at least, in a few cases. Just as a flower garden has been intentionally produced by man, so flowers have been unconsciously produced by insects. As a rule, all bright red, blue, or orange in nature (except in the rare case of gems) is due to animal selection, either of flowers, fruits, or mates. Thus we may say that beauty in the inorganic world is always accidental; but in the organic world it is sometimes accidental and sometimes designed. A waterfall is a mere result of geological and geographical causes, but a bluebell or a butterfly is partly the result of a more or less deliberate æsthetic choice.

A BALLADE OF EVOLUTION.

In the mud of the Cambrian main
 Did our earliest ancestor dive:
From a shapeless albuminous grain
 We mortals our being derive.
He could split himself up into five,
 Or roll himself round like a ball:
For the fittest will always survive,
 While the weakliest go to the wall.

As an active ascidian again
 Fresh forms he began to contrive,
Till he grew to a fish with a brain,
 And brought forth a mammal alive.
With his rivals he next had to strive,
 To woo him a mate and a thrall;
So the handsomest managed to wive,
 While the ugliest went to the wall.

At length as an ape he was fain
 The nuts of the forest to rive;
Till he took to the low-lying plain,
 And proceeded his fellow to knive.
Thus did cannibal men first arrive,
 One another to swallow and maul;
And the strongest continued to thrive,
 While the weakliest went to the wall.

ENVOY.

Prince, in our civilized hive,
 Now money's the measure of all;
And the wealthy in coaches can drive,
 While the needier go to the wall.

CONTENTS.

Beacon Lights of Science

FACTS AND FICTIONS OF ZOOLOGY

By ANDREW WILSON

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WITH NUMEROUS ILLUSTRATIONS.

"Beholding the bright countenance of truth in the quiet and still air of delightful studies."—MILTON.

ZOOLOGICAL MYTHS.

WHEN the country swain, loitering along some lane, comes to a standstill to contemplate, with awe and wonder, the spectacle of a mass of the familiar "hair-eels" or "hair-worms" wriggling about in a pool, he plods on his way firmly convinced that, as he has been taught to believe, he has just witnessed the results of the transformation of some horse's hairs into living creatures. So familiar is this belief to people of professedly higher culture than the countryman, that the transformation just alluded to has to all, save a few thinking persons and zoologists, become a matter of the most commonplace kind. When some quarrymen, engaged in splitting up the rocks, have succeeded in dislodging some huge mass of stone, there may sometimes be seen to hop from among the *débris* a lively toad or frog, which comes to be regarded by the excavators with feelings akin to those of superstitious wonder and amazement. The animal may or may not be captured; but the fact is duly chronicled in the local newspapers, and people wonder for a season over the phenomenon of a veritable Rip Van Winkle of a frog, which, to all appearance, has lived for "thousands of years in the solid rock." Nor do the hair-worm and the frog stand alone in respect of their marvellous origin. Popular zoology is full of such marvels. We find unicorns, mermaids, and mermen; geese developed from the shell-fish known as "barnacles;" we are told that crocodiles may weep, and that sirens can sing—in short, there is nothing so wonderful to be told of animals that people will not believe the tale. Whilst, curiously enough, when they are told of veritable facts of animal life, heads begin to shake and doubts to be expressed, until the zoologist despairs of educating people into distinguishing fact from fiction, and truth from theories and unsupported beliefs. The story told of the old lady, whose youthful

acquaintance of seafaring habits entertained her with tales of the wonders he had seen, finds, after all, a close application in the world at large. The dame listened with delight, appreciation, and belief, to accounts of mountains of sugar and rivers of rum, and to tales of lands where gold and silver and precious stones were more than plentiful. But when the narrator descended to tell of fishes that were able to raise themselves out of the water in flight, the old lady's credulity began to fancy itself imposed upon; for she indignantly repressed what she considered the lad's tendency to exaggeration, saying, "Sugar mountains may be, and rivers of rum may be, but fish that flee ne'er can be!" Many popular beliefs concerning animals partake of the character of the old lady's opinions regarding the real and the fabulous; and the circumstance tells powerfully in favor of the opinion that a knowledge of our surroundings in the world, and an intelligent conception of animal and plant life, should form part of the school-training of every boy and girl, as the most effective antidote to superstitions and myths of every kind.

The tracing of myths and fables is a very interesting task, and it may, therefore, form a curious study, if we endeavor to investigate very briefly a few of the popular and erroneous beliefs regarding lower animals. The belief regarding the origin of the hair-worms is both widely spread and ancient. Shakespeare tells us that

> "Much is breeding,
> Which, like the courser's hair, hath yet but life,
> And not a serpent's poison."

The hair-worms certainly present the appearance of long, delicate black hairs, which move about with great activity amidst the mud of pools and ditches. These worms, in the early stages of their existence, inhabit the bodies of insects, and may be found coiled up within the grasshopper, which thus gives shelter to a guest exceeding many times the length of the body of its host. Sooner or later the hair-worm, or *Gordius aquaticus* as the naturalist terms it, leaves the body of the insect, and lays its eggs, fastened together in long strings, in water. From each egg a little creature armed with minute hooks is produced, and this young hair-worm burrows its way into the body of some insect, there to repeat the history of its parent. Such is the well-ascertained history of the hair-worm, excluding entirely the popular belief in its origin. There certainly does exist in science a theory known as that of "spontaneous generation," which, in ancient times, accounted for the production of insects and other animals by assuming that they were produced in some mysterious fashion out of lifeless matter. But not even the most ardent believer in the extreme modification of this theory which holds a place in modern scientific belief, would venture to maintain the production of a hair-worm by the mysterious vivification of an inert substance such as a horse's hair.

The expression "crocodile's tears" has passed into common use, and it therefore may be worth while noting the probable origin of this myth. Shakespeare, with that wide extent of knowledge which enabled him to draw similes from every department of human thought, says that

> "Gloster's show
> Beguiles him, as the mournful crocodile
> With sorrow snares relenting passengers."

The poet thus indicates the belief that not only do crocodiles shed tears, but that sympathizing passengers, turning to commiserate the reptile's woes, are seized and destroyed by the treacherous creatures. That quaint and credulous old author—the earliest writer of English prose—Sir John Maundeville, in his "Voiage," or account of his "Travaile," published about 1356—in which, by the way, there are to be found accounts of not a few wonderful things in the way of zoological curiosities—tells us that in a certain "contre and be all yonde, ben great plenty of Crokodilles, that is, a manner of a long Serpent as I have seyed before." He further remarks that "these Serpents slew men," and devoured them, weeping; and he tells us, too, that "whan

thei eaten thei meven (move) the over jowe (upper jaw), and nought the nether (lower) jowe: and thei have no tonge (tongue)." Sir John thus states two popular beliefs of his time and of days prior to his age, namely, that crocodiles move their upper jaws, and that a tongue was absent in these animals.

As regards the tears of the crocodile, no foundation of fact exists for the belief in such sympathetic exhibitions. But a highly probable explanation may be given of the manner in which such a belief originated. These reptiles unquestionably emit very loud and singularly plaintive cries, compared by some travellers to the mournful howling of dogs. The earlier and credulous travellers would very naturally associate tears with these cries, and, once begun, the supposition would be readily propagated, for error and myth are ever plants of quick growth. The belief in the movement of the upper jaw rests on an apparent basis of fact. The lower jaw is joined to the skull very far back on the latter, and the mouth-opening thus comes to be singularly wide; whilst, when the mouth opens, the skull and upper jaw are apparently observed to move. This is not the case, however; the apparent movement arising from the manner in which the lower jaw and the skull are joined together. The belief in the absence of the tongue is even more readily explained. When the mouth is widely opened, no tongue is to be seen. This organ is not only present, but is, moreover, of large size; it is, however, firmly attached to the floor of the mouth, and is specially adapted, from its peculiar form and structure, to assist these animals in the capture and swallowing of their prey.

One of the most curious fables regarding animals which can well be mentioned, is that respecting the so-called "Bernicle" or "Barnacle Geese," which by the naturalists and educated persons of the Middle Ages were believed to be produced by those little Crustaceans named "Barnacles." With the "Barnacles" every one must be familiar who has examined the floating drift-wood of the sea-beach, or who has seen ships docked in a seaport town. A barnacle is simply a kind of crab inclosed in a triangular shell, and attached by a fleshy stalk to fixed objects. If the barnacle is not familiar to readers, certain near relations of these animals must be well known, by sight at least, as amongst the most familiar denizens of our sea coasts. These latter are the "Sea-Acorn" or *Balani*, whose little conical shells we crush by hundreds as we walk over the rocks at low-water mark; whilst every wooden pile immersed in the sea becomes coated in a short time with a thick crust of the "Sea-Acorns." If we place one of these little animals, barnacle or sea-acorn—the latter wanting the stalk of the former—in its native waters, we shall observe a beautiful little series of feathery plumes to wave backward and forward, and ever and anon to be quickly withdrawn into the secure recesses of the shell. These organs are the modified feet of the animal, which not only serve for sweeping food-particles into the mouth, but act also as breathing-organs. We may, therefore, find it a curious study to inquire through what extraordinary transformation and confusion of ideas such an animal could be credited with giving origin to a veritable goose; and the investigation of the subject will also afford a singularly apt illustration of the ready manner in which the fable of one year or period becomes transmitted and transformed into the secure and firm belief of the next.

We may begin our investigation by inquiring into some of the opinions which were entertained on this subject and ventilated by certain old writers. Between 1154 and 1189 Giraldus Cambrensis, in a work entitled "Topographia Hiberniæ," written in Latin, remarks concerning "many birds which are called *Bernacæ:* against nature, nature produces them in a most extraordinary way. They are like marsh geese, but somewhat smaller. They are produced from fir timber tossed along the sea, and are at first like gum. Afterward they hang down by their

beaks, as if from a sea-weed attached to the timber, surrounded by shells, in order to grow more freely." Giraldus is here evidently describing the barnacles themselves. He continues: "Having thus, in process of time, been clothed with a strong coat of feathers, they either fall into the water or fly freely away into the air. They derive their food and growth from the sap of the wood or the sea, by a secret and most wonderful process of alimentation. I have frequently, with my own eyes, seen more than a thousand of these small bodies of birds, hanging down on the sea-shore from one piece of timber, inclosed in shells, and already formed." Here, again, our author is speaking of the barnacles themselves, with which he naturally confuses the geese, since he presumes the Crustaceans are simply geese in an undeveloped state. He further informs his readers that, owing to their presumably marine origin, "bishops and clergymen in some parts of Ireland do not scruple to dine off these birds at the time of fasting, because they are not flesh, nor born of flesh," although for certain other and theological reasons, not specially requiring to be discussed in the present instance, Giraldus disputes the legality of this practice of the Hibernian clerics.

In the year 1527 appeared "The Hystory and Croniclis of Scotland, with the cosmography and dyscription thairof, compilit be the noble Clerk Maister Hector Boece, Channon of Aberdene." Boece's "History" was written in Latin; the title we have just quoted being that of the English version of the work (1540), which title further sets forth that Boece's work was "Translatit laitly in our vulgar and commoun langage be Maister Johne Bellenden, Archedene of Murray, And Imprentit in Edinburgh, be me Thomas Davidson, prenter to the Kyngis nobyll grace." In this learned work the author discredits the popular ideas regarding the origin of the geese. "Some men belevis that thir clakis (geese) growis on treis be the nebbis (bills). Bot thair opinoun is vane. And becaus the nature and procreatioun of thir clakis is strange, we have maid na lytyll laboure and deligence to serche ye treuth and verite yairof, we have salit (sailed) throw ye seis quhare thir clakis ar bred, and I fynd be gret experience, that the nature of the seis is mair relevant caus of thair procreatioun than ony uthir thyng." According to Boece, then, "the nature of the seis" formed the chief element in the production of the geese, and our author proceeds to relate how "all treis (trees) that ar cassin in the seis be proces of tyme apperis first wormeetin (worm-eaten), and in the small boris and hollis (holes) thairof growis small worms." Our author no doubt here alludes to the ravages of the *Teredo*, or ship-worm, which burrows into timber, and with which the barnacles themselves are thus confused. Then he continues, the "wormis" first "schaw (show) thair heid and feit, and last of all thay schaw thair plumis and wyngis. Finaly, quhen thay ar cumyn to the just mesure and quantite of geis, thay fle in the aire as othir fowlis dois, as was notably provyn, in the yeir of God ane thousand iii hundred lxxxx, in sicht of mony pepyll, besyde the castell of Petslego." On the occasion referred to, Boece tells us that a great tree was cast on shore, and was divided, by order of the "lard" of the ground, by means of a saw. Wonderful to relate, the tree was found not merely to be riddled with a "multitude of wormis," throwing themselves out of the holes of the tree, but some of the "wormis" had "baith heid, feit, and wyngis," but, adds the author, "they had no fedderis (feathers)."

Unquestionably, either the scientific use of the imagination had operated in this instance in inducing the observers to believe that in this tree, riddled by the ship-worms and possibly having barnacles attached to it, they beheld young geese; or Boece had construed the appearances described as those representing the embryo stages of the barnacle geese.

Boece further relates how a ship named the *Christofir* was brought to Leith, and was broken down because her timbers had grown old and failing.

In these timbers were beheld the same "wormeetin" appearances, "all the hollis thairof" being "full of geis." Boece again most emphatically rejects the idea that the "geis" were produced from the wood of which the timbers were composed, and once more proclaims his belief that the "nature of the seis resolvit in geis" may be accepted as the true and final explanation of their origin. A certain "Maister Alexander Galloway" had apparently strolled with the historian along the sea-coast, the former giving "his mynd with maist ernist besynes to serche the verite of this obscure and mysty dowtis." Lifting up a piece of tangle, they beheld the sea-weed to be hanging full of mussel-shells from the root to the branches. Maister Galloway opened one of the mussel-shells, and was "mair astonist than afore" to find no fish therein, but a perfectly shaped "foule, smal and gret," as corresponded to the "quantity of the shell." And once again Boerce draws the inference that the trees or wood on which the creatures are found have nothing to do with the origin of the birds; and that the fowls are begotten of the "occeane see, quhilk," concludes our author, "is the caus and production of mony wonderful thingis."

More than fifty years after the publication of Boece's "History," old Gerard of London, the famous "master in chirurgerie" of his day, gave an account of the barnacle goose, and not only entered into minute particulars of its growth and origin, but illustrated its manner of production by means of the engraver's art of his day. Gerard's "Herball," published in 1597, thus contains, amongst much that is curious in medical lore, a very quaint piece of zoological history. He tells us that "in the north parts of Scotland, and the Ilands adjacent, called Orchades (Orkneys)," are found "certaine trees, whereon doe growe certaine shell fishes, of a white colour tending to russet; wherein are conteined little living creatures: which shels in time of maturitie doe open, and out of them grow those little living foules whom we call Barnakles, in the north of England Brant Geese, and in Lancashire tree Geese; but the other that do fall upon the land, perish, and come to nothing: thus much by the writings of others, and also from the mouths of people of those parts, which may," concludes Gerard, "very well accord with truth."

Not content with hearsay evidence, however, Gerard relates what his eyes saw and hands touched. He describes how on the coasts of a certain "small Iland in Lancashire called Pile of Foulders" (probably Peel Island), the wreckage of ships is cast up by the waves, along with the trunks and branches "of old and rotten trees."

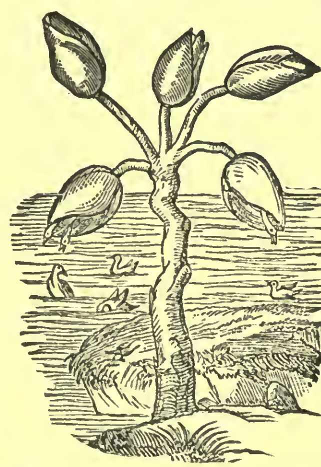

Fig. 1.—The Barnacle Tree (from Gerard's "Herball").

On these wooden rejectamenta "a certaine spume or froth" grows, according to Gerard. This spume "in time breedeth unto certaine shels, in shape like those of the muskle, but sharper pointed, and of a whitish colour." This description, it may be remarked, clearly applies to the barnacles themselves. Gerard then continues to point out how, when the shell is perfectly formed, it "gapeth open, and the first thing that appeereth is the foresaid lace or string"—the substance described by Gerard as contained within the shell—"next come the legs of the Birde hanging out; and as it groweth greater, it openeth the shell by degrees,

till at length it is all come forth, and hangeth only by the bill; in short space after it commeth to full maturitie, and falleth into the sea, where it gathereth feathers, and groweth to a foule, bigger than a Mallard, and lesser than a Goose, having blacke legs and bill or beake, and feathers blacke and white . . . which the people of Lancashire call by no other name than a tree Goose."

Accompanying this description is the engraving of the bernicle tree (Fig. 1) bearing its geese-progeny. From the open shells in two cases, the little geese are seen protruding, whilst several of the fully fledged fowls are disporting themselves in the sea below. Gerard's concluding piece of information, with its exordium, must not be omitted. "They spawne," says the wise apothecary, "as it were, in March or Aprill; the Geese are found in Maie or June, and come to fulnesse of feathers in the moneth after. And thus hauing, through God's assistance, discoursed somewhat at large of Grasses, Herbes, Shrubs, Trees, Mosses, and certaine excrescences of the earth, with other things moe incident to the Historie thereof, we conclude and end our present volume, with this woonder of England. For which God's name be euer honored and praised." It is to be remarked that Gerard's description of the goose-progeny of the barnacle tree exactly corresponds with the appearance of the bird known to ornithologists as the "barnacle-goose;" and there can be no doubt that, skilled as was this author in the natural-history lore of his day, there was no other feeling in his mind than that of firm belief in and pious wonder at the curious relations between the shells and their fowl-offspring. Gerard thus attributes the origin of the latter to the barnacles. He says nothing of the "wormeetin" holes and burrows so frequently mentioned by Boece, nor would he have agreed with the latter in crediting the "nature of the occeane see" with their production, save in so far as their barnacle-parents lived and existed in the waters of the ocean.

The last account of this curious fable which we may allude to in the present instance is that of Sir Robert Moray, who, in his work entitled "A Relation concerning Barnacles," published in the "Philosophical Transactions" of the Royal Society in 1677-78, gives a succinct account of these crustaceans and their bird-progeny. Sir Robert is described as "lately one of his Majesties Council for the Kingdom of Scotland," and we may therefore justly assume his account to represent that of a cultured, observant person of his day and generation. The account begins by remarking that the "most ordinary trees" found in the western island of Scotland "are Firr and Ash." "Being," continues Sir Robert, "in the Island of East (Uist), I saw lying upon the shore a cut of a large Firr tree of about 2½ foot diameter, and 9 or 10 foot long; which had lain so long out of the water that it was very dry: And most of the shells that had formerly cover'd it, were worn or rubb'd off. Only on the parts that lay next the ground, there still hung multitudes of little Shells; having within them little Birds, perfectly shap'd, supposed to be Barnacles." Here again the description applies to the barnacles; the "little birds" they are described as containing being of course the bodies of the shell-fish.

"The Shells," continues the narrator, "hang at the Tree by a Neck longer than the Shell;" this "neck" being represented by the stalk of the barnacle. The neck is described as being composed "of a kind of filmy substance, round, and hollow, and creassed, not unlike the Wind-pipe of a Chicken; spreading out broadest where it is fastened to the Tree, from which it seems to draw and convey the matter which serves for the growth and vegetation of the Shell and the little Bird within it." Sir Robert Moray therefore agrees in respect of the manner of nourishment of the barnacles with the opinion of Giraldus already quoted. The author goes on to describe the "Bird" found in every shell he opened; remarking that "there appeared nothing wanting as to the internal parts, for making up a perfect Sea-fowl:

every little part appearing so distinctly, that the whole looked like a large Bird seen through a concave or diminishing Glass, colour and feature being everywhere so clear and neat." The "Bird" is most minutely described as to its bill, eyes, head, neck, breast, wings, tail and feet, the feathers being "everywhere perfectly shaped, and blackish-coloured. All being dead and dry," says Sir Robert, "I did not look after the Internal parts of them," a statement decidedly inconsistent with his previous assertion as to the perfect condition of the "internal parts;" and he takes care to add, "nor did I ever see any of the little Birds alive, nor met with anybody that did. Only some credible persons," he concludes, "have assured me they have seen some as big as their fist."

This last writer thus avers that he saw little birds within the shells he clearly enough describes as those of the barnacles. We must either credit Sir Robert with describing what he never saw, or with misconstruing what he did see. His description of the goose corresponds with that of the barnacle goose, the reputed progeny of the shells; and it would, therefore, seem that this author, with the myth at hand, saw the barnacles only with the eyes of a credulous observer, and thus beheld, in the inside of each shell—if, indeed, his research actually extended thus far—the reproduction in miniature of a goose, with which, as a mature bird, he was well acquainted.

Annexed is a woodcut, copied from Munster's "Cosmography" (1550), a very popular book in its time, showing the tree with its fruit, and the geese which are supposed to have just escaped from it.

FIG. 2.—Barnacle Tree (from Munster's "Cosmography").

This historical ramble may fitly preface what we have to say regarding the probable origin of the myth. By what means could the barnacles become credited with the power of producing the well-known geese? Once started, the progress and growth of the myth are easily accounted for. The mere transmission of a fable from one generation or century to another is a simply explained circumstance, and one exemplified by the practices of our own times. The process of accretion and addition is also well illustrated in the perpetuation of fables; since the tale is certain to lose nothing in its historical journey, but, on the contrary, to receive additional elaboration with increasing age. Professor Max Müller, after discussing

various theories of the origin of the barnacle myth, declares in favor of the idea that confusion of language and alteration of names lie at the root of the error. The learned author of the "Science of Language" argues that the true barnacles were named, properly enough, *Bernaculæ*, and lays stress on the fact that bernicle geese were first caught in Ireland. That country becomes *Hibernia* in Latin, and the Irish geese were accordingly named *Hibernicæ*, or *Hiberniculæ*. By the omission of the first syllable—no uncommon operation for words to undergo—we obtain the name *Berniculæ* for the geese, this term being almost synonymous with the name *Bernaculæ* already applied, as we have seen, to the barnacles. Bernicle geese and bernicle shells, confused in name, thus became confused in nature ; and, once started, the ordinary process of growth was sufficient to further intensify, and render more realistic, the story of the bernicle tree and its wonderful progeny.

By way of a companion legend to that of the barnacle tree, we may select the story of the "Lamb Tree" of Cathay, told by Sir John Maundeville, whose notes of travel regarding crocodiles' tears, and other points in the confirmation of these reptiles, have already been referred to. Sir John, in that chapter of his work which treats "Of the Contries and Yles that ben bezonde the Lond of Cathay ; and of the Frutes there," etc., relates that in Cathay "there growethe a manner of Fruyt, as thoughe it were Gowrdes : and whan thei ben rype, men kutten (cut) hem a to (them in two), and men fynden with inne a lytylle Best (beast), in Flessche in Bon and Blode (bone and blood) as though it were a lytylle Lomb (lamb) with outen wolle (without wool). And men eten both the Frut and the Best ; and that," says Sir John, "is a great marveylle. Of that frut," he continues, "I have eten ; alle thoughe it were wondirfulle"—this being added, no doubt, from an idea that there might possibly be some stay-at-home persons who would take Sir John's statement *cum grano salis*. "But," adds this worthy "knyght of Ingelond," "I knowe wel that God is marveyllous in His Werkes." Not to be behind the inhabitants of Cathay in a tale of wonders, the knight related to these Easterns "als gret a marveylle to hem that is amonges us ; and that was of the Bernakes. For I tolde hem hat in oure Countree weren Trees that beren a Fruyt, that becomen Briddes (birds) fleeynge : and tho that fellen in the Water lyven (live) ; and thei that fallen on the Erthe dyen anon : and thei ben right gode to mannes mete (man's meat). And here had thei als gret marvayle," concludes Sir John, "that sume of hem trowed it were an impossible thing to be." Probably the inhabitants of Cathay, knowing their own weakness as regards the lamb tree, might possess a fellow-feeling for their visitor's credulity, knowing well, from experience, the readiness with which a "gret marvayle" could be evolved and sustained.

Passing from the sphere of the mythical and marvellous as represented in mediæval times, we may shortly discuss a question, which, of all others, may justly claim a place in the records of zoological curiosities—namely, the famous and oft-repeated story of the "Toad from the solid rock," as the country newspapers style the incident. Regularly, year by year, and in company with the reports of the sea-serpent's reappearance, we may read of the discoveries of toads and frogs in situations and under circumstances suggestive of a singular vitality on the part of the amphibians, of more than usual credulity on the part of the hearers, or of a large share of inventive genius in the narrators of such tales. The question possesses for every one a certain degree of interest, evoked by the curious and strange features presented on the face of the tales. And it may therefore not only prove an interesting but also a useful study, if we endeavor to arrive at some just and logical conceptions of these wonderful narrations.

Instances of the discovery of toads and frogs in solid rocks need not be specially given ; suffice it to say, that

these narratives are repeated year by year with little variation. A large block of stone or face of rock is detached from its site, and a toad or frog is seen hereafter to be hopping about in its usual lively manner. The conclusion to which the bystanders invariably come is that the animal must have been contained within the rock, and that it was liberated by the dislodgment of the mass. Now, in many instances, cases of the appearance of toads during quarrying operations have been found, on close examination, to present no evidence whatever that the appearance of the animals was due to the dislodgment of the stones. A frog or toad may be found hopping about among some recently formed *dêbris*, and the animal is at once seized upon and reported as having emerged from the rocks into the light of day. There is in such a case not the slightest ground for supposing any such thing; and the animal may more reasonably be presumed to have simply hopped into the *dêbris* from its ordinary habitat. But laying aside narratives of this kind, which lose their plausibility under a very commonplace scrutiny, there still exist cases, reported in an apparently exact and truthful manner, in which these animals have been alleged to appear from the inner crevices of rocks after the removal of large masses of the formations. We shall assume these latter tales to contain a plain, unvarnished statement of what was observed, and deal with the evidence they present on this footing.

One or two notable examples of such verified tales are related by Smellie, in his "Philosophy of Natural History." Thus, in the "Memoirs of the French Academy of Sciences" for 1719, a toad is described as having been found in the heart of an elm tree; and another is stated to have been found in the heart of an old oak tree, in 1731, near Nantz. The condition of the trees is not expressly stated, nor are we afforded any information regarding the appearance of the toads—particulars of considerable importance in view of the suggestions and explanations to be presently brought forward. Smellie himself, while inclined to be sceptical in regard to the truth or exactness of many of the tales told of the vitality of toads, yet regards the matter as affording food for reflection, since he remarks, "But I mean not to persuade, for I cannot satisfy myself; all I intend is, to recommend to those gentlemen who may hereafter chance to see such rare phenomena, a strict examination of every circumstance that can throw light upon a subject so dark and mysterious; for the vulgar, ever inclined to render uncommon appearances still more marvellous, are not to be trusted."

This author strikes the key-note of the inquiry in his concluding words, and we shall find that the explanation of the matter really lies in the clear understanding of what are the probabilities, and what the actual details, of the cases presented for consideration. We may firstly, then, glance at a few of the peculiarities of the frogs and toads, regarded from a zoological point of view. As every one knows, these animals emerge from the egg in the form of little fish-like "tadpoles," provided with outside gills, which are soon replaced by inside gills, resembling those of fishes. The hind legs are next developed, and the fore limbs follow a little later; whilst, with the development of lungs, and the disappearance of the gills and tail, the animal leaves the water, and remains for the rest of its life an air-breathing, terrestrial animal. Then, secondly, in the adult frog or toad, the naturalist would point to the importance of the skin as not only supplementing, but, in some cases, actually supplanting the work of the lungs as the breathing organ. Frogs and toads will live for months under water, and will survive the excision of the lungs for like periods; the skin in such cases serving as the breathing surface. A third point worthy of remembrance is included in the facts just related, and is implied in the information that these animals can exist for long periods without food, and with but a limited supply of air. We can under-

stand this toleration on the part of these animals when we take into consideration their cold-blooded habits, which do not necessitate, and which are not accompanied by, the amount of vital activity we are accustomed to note in higher animals. And, as a last feature in the purely scientific history of the frogs and toads, it may be remarked that these animals are known to live for long periods. One pet toad is mentioned by a Mr. Arscott as having attained, to his knowledge, the age of thirty-six years ; and a greater age still might have been recorded of this specimen, but for the untoward treatment it sustained at the hands, or rather beak, of a tame raven. In all probability it may be safely assumed that, when the conditions of life are favorable, these creatures may attain a highly venerable age —regarding the lapse of time from a purely human and interested point of view.

We may now inquire whether or not the foregoing considerations may serve to throw any light upon the tales of the quarryman. The first point to which attention may be directed is that involved in the statement that the amphibian has been imprisoned in a *solid* rock. Much stress is usually laid on the fact that the rock was solid ; this fact being held to imply the great age, not to say antiquity, of the rock and its supposed tenant. The impartial observer, after an examination of the evidence presented, will be inclined to doubt greatly the justification for inserting the adjective " solid ;" for usually no evidence whatever is forthcoming as to the state of the rock prior to its removal. No previous examination of the rock is or can be made, from the circumstance that no interest can possibly attach to its condition until its removal reveals the apparent wonder it contained, in the shape of the live toad. And it is equally important to note that we rarely, if ever, find mention of any examination of the rock being made subsequently to the discovery. Hence, a first and grave objection may be taken to the validity of the supposition that the rock was solid, and it may be fairly urged that on this supposition the whole question turns and depends. For if the rock cannot be proved to have been impermeable to and barred against the entrance of living creatures, the objector may proceed to show the possibility of the toad having gained admission, under certain notable circumstances, to its prison-house.

The frog or toad in its young state, and having just entered upon its terrestrial life, is a small creature, which could, with the utmost ease, wriggle into crevices and crannies of a size which would almost preclude such apertures being noticed at all. Gaining access to a roomier crevice or nook within, and finding there a due supply of air, along with a dietary consisting chiefly of insects, the animal would grow with tolerable rapidity, and would increase to such an extent that egress through its aperture of entrance would become an impossibility. Next, let us suppose that the toleration of the toad's system to starvation and to a limited supply of air is taken into account, together with the fact that these creatures will hibernate during each winter, and thus economize, as it were, their vital activity and strength ; and after the animal has thus existed for a year or two—no doubt under singularly hard conditions—let us imagine that the rock is split up by the wedge and lever of the excavator. We can then readily enough account for the apparently inexplicable story of " the toad in the rock." " There is the toad and here is the solid rock," say the gossips. " There is an animal which has singular powers of sustaining life under untoward conditions, and which, in its young state, could have gained admittance to the rock through a mere crevice," says the naturalist in reply. Doubtless, the great army of the unconvinced may still believe in the tale as told them ; for the weighing of evidence and the placing *pros* and *cons* in fair contrast are not tasks of congenial or wonted kind in the ordinary run of life. Some people there will be who will believe in the original solid rock and its toad, despite the assertion of

the geologist that the earliest fossils of toads appear in almost the last-formed rocks, and that a live toad in rocks of very ancient age—presuming, according to the popular belief, that the animal was inclosed when the rock was formed—would be as great an anomaly and wonder as the mention, as an historical fact, of an express train or the telegraph in the days of the patriarchs. In other words, the live toad which hops out of an Old Red Sandstone rock must be presumed, on the popular belief, to be older by untold ages than the oldest *fossil* frogs and toads. The reasonable mind, however, will ponder and consider each feature of the case, and will rather prefer to countenance a supposition based on ordinary experience, than an explanation brought ready-made from the domain of the miraculous; whilst not the least noteworthy feature of these cases is that included in the remark of Smellie, respecting the tendency of uneducated and superstitious persons to magnify what is uncommon, and in his sage conclusion that as a rule such persons in the matter of their relations "are not to be trusted."

But it must also be noted that we possess valuable evidence of a positive and direct kind bearing on the duration of life in toads under adverse circumstances. As this evidence tells most powerfully against the supposition that the existence of those creatures can be indefinitely prolonged, it forms of itself a veritable court of appeal in the cases under discussion. The late Dr. Buckland, curious to learn the exact extent of the vitality of the toad, caused, in the year 1825, two large blocks of stone to be prepared. One of the blocks was taken from the oolite limestone, and in this first stone twelve cells were excavated. Each cell was one foot deep and five inches in diameter. The mouth of each cell was grooved so as to admit of two covers being placed over the aperture; the first or lower cover being of glass, and the upper one of slate. Both covers were so adapted that they could be firmly luted down with clay or putty; the object of this double protection being that the slate cover could be raised so as to inspect the contained object through the closed glass cover without admitting air. In the second or sandstone block, a series of twelve cells was also excavated; these latter cells, being, however, of smaller size than those of the limestone block, each cell being only six inches in depth by five inches in diameter. These cells were likewise fitted with double covers.

On November 26th, 1825, a live toad—kept for some time previously to ensure its being healthy—was placed in each of the twenty-four cells. The largest specimen weighed 1185 grains, and the smallest 115 grains. The stones and the immured toads were buried on the day mentioned, three feet deep, in Dr. Buckland's garden. There they lay until December 10th, 1826, when they were disinterred and their tenants examined. All the toads in the smaller cells of the sandstone block were dead, and from the progress of decomposition it was inferred that they had succumbed long before the date of disinterment. The majority of the toads in the limestone block were alive, and, curiously enough, one or two had actually increased in weight. Thus, No. 5, which at the commencement of its captivity had weighed 1185 grains, had increased to 1265 grains; but the glass cover of No. 5's cell was found to be cracked. Insects and air must therefore have obtained admittance and have afforded nourishment to the imprisoned toad; this supposition being rendered the more likely by the discovery that in one of the cells, the covers of which were also cracked and the tenant of which was dead, numerous insects were found. No. 9, weighing originally 988 grains, had increased during its incarceration to 1116 grains; but No. 1, which in the year 1825 had weighed 924 grains, was found in December, 1826, to have decreased to 698 grains; and No. 11, originally weighing 936 grains, had likewise disagreed with the imprisonment, weighing only 652 grains when examined in 1826.

At the period when the blocks of stone were thus prepared, four toads were pinned up in holes five inches

deep and three inches in diamcter, cut in the stem of an apple tree ; the holes being firmly plugged with tightly fitting wooden plugs. Thesc four toads were found to be dead when examined along with the others in 1826 ; and of four othcrs inclosed in basins madc of plaster of Paris, and which were also buricd in Dr. Buckland's garden, two were found to be dead at the end of a year, their comrades being alive, but looking starved and meagrc. The toads which were found alive in the limestone block in December, 1826, werc again immured and buried, but were found to be dead, without leaving a single survivor, at the end of the second year of their imprisonment.

These experiments may fairly be said to prove two points. They firstly show that under cirumstances even of a favorablc kind when compared with the condition popularly believed in—namely, that of being inclosed in a *solid* rock—the limit of thc toad's life may be assumed to be within two years ; this period being no doubt capable of being extended when the animal gains a slight advantage, exemplified by the admission of air and insect-food. Secondly, we may reasonably argue that these experiments show that toads when rigorously treated, like other animals, become starved and meagre, and by no means resemble the lively, well-fed animals reported as having emerged from an imprisonment extcnding, in popular estimation, through periods of inconceivable duration.

These tales are, in short, as devoid of actual foundation as are the modern beliefs in the venomous properties of the toad, or the ancient beliefs in the occult and mystic powers of various parts of its frame when used in incantations. Shakespeare, whilst attributing to the toad venomous qualities, has yet immortalized it in his famous simile by crediting it with the possession of a "precious jewel." But even in the latter case the animal gets but scant justice ; for science strips it of its poetical reputation, and in this, as in other respects, shows it, despite fable and myth, to be zoologically an interesting, but otherwise a commonplace member of the animal series.

THE SEA-SERPENTS OF SCIENCE.

"There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy."
Hamlet.

In the dull season of the year, when therc is a decided lack of interesting or startling events, and whcn newspaper editors are at their wits' end for material, three objects derived from the domain of the biologist have been creditcd with the task of reviving the tide of public interest, and of restoring peace and composure to the editorial mind. It need hardly be said that the three objects alluded to are : "the frog from the solid rock," "the gigantic gooseberry"—occasionally supplcmented by the discovery of "an egg of marvellous proportions"—and last, though by no means least, comes the announcement —made as if the being were some eminent tragedian returning to the scene of former triumphs—of the "reappearance of the great sea-serpent !" People have come in fact to regard the annual advent of the "Great Unknown" as a sure and settled event ; and doubtless there are many who would confess to a feeling of disappointment did the season slip past without an announcement of the mysterious stranger's visit.

Notwithstanding the interest which the discussion of the sea-scrpent question inevitably evokes, there are comparatively few persons to be found who regard the question from other than a purely sceptical point of view. The intelligence that the sea-serpent "has been seen again" is usually reckoned as equivalent to the statement that some grog-laden mariner has becn exhibiting that phenomenon known to physiologists as "unconscious cerebration ;" or that some obscrver has been interpreting an unusual appearance in the sea by the light of the serpentine myth. Occasionally the subject affords an opportunity for the display of the anything but scientific use of the imagination of

some feeble jokers, who succeed in imposing upon the credulity of editors, and in seeing their absurd descriptions of fictitious animals in all the prominence of large type. I have before me at the present time a most circumstantial account of the "capture of the sea-serpent at Oban," in which the animal is described as having been attacked by a file of volunteers armed with rifles, and by a perfect flotilla of yachts and boats. The animal was, according to this account, happily delivered over to the tender mercies of the native talent. After causing stones to fly in showers by the sweep of its tail as it lay on the beach, it was secured, and a list of zoological characters such as belong to no one known animal is duly given. It can hardly be deemed astonishing that a non-scientific London *entrepreneur*, on reading the account of the monster's capture, at once telegraphed to secure it for exhibition. History, it need scarcely be said, does not record the sayings of this gentleman on learning that, as one of the credulous public, he had been duly hoaxed.

The literature of the subject is in one sense a huge record of mistakes and errors in observation, and the ordinary public, as well as the scientific world, have long been accustomed to accept the erroneous side as representative of the entire subject, and as if no element or substratum of probability and fact was included in the whole matter. Thus, for example, because on one occasion an alleged sea-serpent on closer investigation was proved to consist of a long train or tail of sea-weed, with some heterogeneous material serving for the head—or since, on other occasions forms described as being of serpentine size have resolved themselves into shoals of porpoises swimming in line—readers of such detached statements are apt to rush to the settled conclusion that all sea-serpent tales are explicable on some analogous footing. The relegation of the subject to the sphere of fable is therefore to be accounted a perfectly natural result of the almost invariable construction put upon a few ill-founded tales and mediæval myths—to be presently alluded to—and also of the indifference with which zoologists themselves have treated the subject; while ignorance of the existence of a great body of perfectly reliable evidence supporting the view that large serpentine forms have been seen, together with a common incompetence to weigh evidence and to decide upon the merits of the case, may also be cited as two important factors in inducing a general disbelief in the personality of the modern Leviathan.

Of the older chroniclers of sea-serpent lore, perhaps the most noteworthy is Olaus Magnus, the worthy archbishop of Upsala, who devotes a whole chapter in the course of his writings to the sea-serpent, and discourses most volubly upon the marine snake, and other monsters of the deep, such as krakens, whales, and the like. Speaking of some sea monsters, the exact nature of which it is zoologically impossible to define, Magnus writes that "their forms are horrible, their heads square, all set with prickles, and they have sharp and long horns about, like a tree rooted up by the roots. They are ten or twelve cubits long, very black, and with huge eyes, the compass whereof is about eight or ten cubits. The apple of the eye is of one cubit, and is red and fiery colored, which in the dark night appears to fishermen afar off under waters as a burning fire, having hairs like goose feathers, thick and long, like a beard hanging down. The rest of the body, for the greatness of the head, which is square, is very small, not being above 14 or 15 cubits long. One of these sea monsters will easily drown many great ships, provided with many strong mariners."

The sea-serpent of this writer appears to have been a terrible animal, worthy of a place in the records of those knightly encounters with strange beasts which mark our earlier literature. The marine snake of Magnus was 200 feet long, twenty feet thick, and appeared "like a pillar" when he elevated his head in mid-air. His hair was a cubit long, his scales were sharp and his skin black; and his eyes were like flaming

fire. The appearances of such monsters were naturally regarded in the light of grave portents of coming disasters. One old writer, relating the capture of a marine monster, says that "in 1282, there was a fish taken in the sea, in all respects like unto a lyon." The fishermen reported that "the fishe gave many frighfull scrikes and cries when it was taken, and at this time," continues the narrative, "there fell a great discord between the Englishmen that were students in Paris and those of Pycardy that studyed there likewise. Their division was so terrible that it could hardly be appeased." Starting thus with a basis of myth, it is little to be wondered at that modern ideas have continued to invest the "sea-serpent" and its kind with an atmosphere of the ridiculous.

The simple and attentive consideration of the matter, however, reveals certain aspects and features, in virtue of which it can hardly be dismissed from the sphere either of popular or of scientific thought, and which commend the subject to the intelligent mind, as a study of both a curious and highly interesting kind. Can we, for example, after perusing the mass of evidence accumulated during past years, dismiss the subject *simpliciter*, as founded on no basis of fact? The answer to such a question must be an emphatic negative; since the evidence brought before our notice includes the testimony of several hundreds of sane and reasonable persons, who in frequent cases have testified on oath and by affidavit to the truth of their descriptions of curious marine forms, seen and observed in various seas. The second supposition, that all of these persons have simply been deceived, is one which must also be dismissed. For, after making all due allowance for exaggeration, and for variations in accounts arising from different modes of expression and even from mental peculiarities in the witnesses, there remains a solid body of testimony, which, unless there is some special tendency to mendacity on the part of persons who travel by sea, we are bound, by all the rules of fair criticism and of evidence, to receive as testimony of honest kind. As I have elsewhere observed, "There are very many calmly and circumstantially related and duly verified accounts of serpentine, or, at any rate, of anomalous marine forms, having been closely inspected by the crews and passengers of vessels. Either, therefore, we must argue that in every instance the sense of intelligent men and women must have played them false, or we must simply assume that they are describing what they have never seen. The accounts in many instances so minutely describe the appearance of such forms, inspected from a near standpoint, that the possibility of their being mistaken for inanimate objects, as they might be if viewed from a distance, is rendered entirely improbable. We may thus, then, affirm firstly that there are many verified pieces of evidence on record, of strange marine forms having been met with—which evidences, judged according to ordinary and common-sense rules, go to prove that certain hitherto undescribed marine organisms do certainly exist in the sea-depth."

The first issue I must therefore submit to the reader, as representing one of a large and impartial jury, is, that the mass of evidence accumulated on the sea-serpent question, when weighed and tested, even in a *primâ facie* manner, plainly shuts us up to the belief that appearances, resembling those produced by the presence in the sea of huge serpentine forms, have been frequently noted by competent and trustworthy observers. Unless we are to believe that men and women have deliberately prevaricated, and that without the slightest excuse or show of reason, we must believe that they have witnessed marine appearances, certainly of unwonted and unusual kind. That "something" has assuredly been seen, must be the verdict on this first issue. What that "something" is or was, and whether or not the evidence will support the opinion that the appearances described bear out the existence of a "sea-serpent" in the flesh, form points for discussion in the next instance.

In the consideration of this second issue, two chief aspects are presented. We have thus, firstly, to assure ourselves that the evidence, the character of which has just been discussed, will support the assertion that the appearances noted were produced by *living organisms.* And provided this point be decided in the affirmative, we must assure ourselves, in the second place, of the probable *kind* and *nature* of these beings.

Allusion has already been made to erroneous observations, which have subjected the stories of sea-serpents to almost universal ridicule, and in which various *lifeless* objects were at first credited with the representation of the marine monster. That a long and connected string of seaweed, extending for some fifty or sixty feet along the surface of a sea, slightly disturbed by a rippling breeze, may be moved by the waves in a manner strongly suggestive of the movements of a snake in swimming, is a statement to the correctness of which I can bear personal testimony, and to the truth of which even observant sea-side visitors may testify. The movements of an unusually long frond or group of fronds of tangle, attached to a rock, and set in motion at low water, by a light swell, has before now, and when seen indistinctly, suggested the idea of the existence at the spot of some large denizen of the sea, browsing on the sea-weeds, with the fore part of its body, represented by the tangle fronds, occasionally appearing at the surface of the water. Floating trunks and roots of trees, serving as a nucleus around which sea-weed has collected, and to which barnacles and sea-acorns—producing a variegated effect by reason of their light color—have attached themselves in great numbers, have also presented appearances closely resembling those of large marine animals swimming slowly along at the surface of the water. In one instance of this latter kind, related to me by a friend who was an actual spectator, the floating piece of timber assumed a shape imitating in the closest and most remarkable manner the head of some reptile—by the same rule, I suppose, that in the gnarled trunks and branches of trees one may frequently discern likenesses to the human face and to the forms of other living things. In this latter instance, the floating object was perceived at some miles' distance from the deck of a yacht ; and even when seen through a telescope, and carefully scrutinized by men accustomed to make out the contour and nature of objects at sea, the resemblance to the head of some animal was so close that the course of the vessel was changed and the object in due time overhauled. This latter, therefore, presents an example of a case, the details of which, when related, tempt people to maintain without further parley, that sea-serpents always resolve themselves into inanimate objects of one kind or another. And so great in some minds is the fear of popular ridicule regarding this subject, that one ship-captain related that when a sea-serpent had been seen by his crew from the deck of the vessel, he remained below ; since to use his own words, "had I said I had seen the sea-serpent, I should have been considered to be a warranted liar all my life after !"

But the natural supposition and remark of the inanimate nature of objects seen at sea is at once noted to be anything but universal in its nature and application, when the records of sea-serpent history are examined in detail. Numerous cases exist in which the object, presumed to be a living being, has been scrutinized so closely that, save on the supposition that senses have played their owners false, or that minds have given way to an unaccountable impulse for lying, we must face and own the belief that living animals have been seen. Let us briefly examine one or two of the accounts of this kind which have been duly and faithfully recorded, with a view of ascertaining whether or not we may detect any inherent or implied elements of improbability, and whether the evidence as to living things having been seen is of trustworthy kind.

One of the most circumstantially recorded and best-known reports of the

appearance of a sea-serpent is that of Captain M'Quhæ, who commanded H. M. S. Dædalus, in 1848, and whose case, originally published and commented upon in the *Times* of that year, may be almost unknown to the present and rising generation of readers. The first announcement in the *Times* appeared in the form of a paragraph on October 9th, 1848, stating that when the Dædalus was on her passage home from the East Indies, and when between the Cape of Good Hope and St. Helena, the captain and most of the officers and crew saw an animal which from its form and shape they assumed to be a sea-serpent. Captain M'Quhæ's own statement, contained in his reply to an official inquiry from the admiralty, gives the date of the marine monster's appearance as 6th August, 1848, and its exact habitat, at 5 P.M. of that day, as latitude 24° 44′ S, and longitude 9° 22′ E. The captain simply states it to be "an enormous serpent, with head and shoulders kept about four feet constantly above the surface of the sea, and, as nearly as we could approximate by comparing it with the length of what our maintop-sail yard would show in the water, there was at the very least sixty feet of the animal *à fleur d'eau*, no portion of which was, to our perception, used in propelling it through the water, either by vertical or horizontal undulation." The animal, Captain M'Quhæ states—and the observation is important, as bearing on the question of the living nature of the object described—passed the ship, "rapidly, but so close under our lee quarter, that had it been a man of my acquaintance I should easily have recognized his features with the naked eye." The further dimensions of the animal are given as 15 or 16 inches in diameter "behind the head, which was," continues Captain M'Quhæ, "without any doubt, that of a snake," while the color is described as being "a dark brown, with yellowish white about the throat." No fins were visible, but it appeared to possess "something like the mane of a horse, or rather (like ?) a bunch of sea-weed, washed about its back." Lieutenant Drummond, of the Dædalus, who was officer of the watch on the memorable occasion, states in his report that the animal had a "back fin," which was "perhaps twenty feet in the rear of the head." This fin evidently corresponds to the structure described in the captain's report as "something like the mane of a horse," and which the introduction of the word "like" (as I have inserted it in parenthesis after the word "rather" in his description) serves to correlate with the "bunch of sea-weed" which "washed about its back."

So far as an exact and circumstantial description, attested by the narrative of other witnesses, can testify to the actual nature of an object, viewed, it must be remarked, by educated and observant men, the instance just given would appear to admit of not the slightest doubt that a truly living and actively moving animal was observed, and also that its appearance was decidedly serpentine. It is noteworthy that in the whole course of the discussion which followed upon the publication of Captain M'Quhæ's observation, no one was found even to suggest that the appearance was other than that of a living animal; although, as will afterwards be remarked, opinions varied greatly as to the nature of the being which thus afforded so tantalizing and insufficient a glimpse of its structure and identity.

Passing over many interesting reports of sea-serpents' appearances now of some years' date, I find in the daily newspapers, almost of the date at which these words are penned, statements, both made on oath and before legal authorities, regarding the "great unknown." The first of these statements I shall give in the words of the newspaper reports, which present a clear, unvarnished statement of the narrative, and of the circumstances in which it was offered for public investigation.

"The story of the mate and crew of the barque Pauline, of London, said to have arrived in port from a twenty months' voyage to Akyab—about having seen 'a sea-serpent' while on a voyage in the Indian seas, was declared

to on oath before Mr. Raffles, the stipendiary magistrate, at the Liverpool Police Court. The affidavit was made in consequence of the doubtfulness with which anything about the 'sea-serpent' has hitherto been received; and to show the genuine character of the story it has been placed judicially on record. The following is a copy of the declaration, which will be regarded as unprecedented in its way :—

BOROUGH OF LIVERPOOL, IN THE COUNTY PALATINE OF LANCASTER, TO WIT.

We, the undersigned, captain, officers, and crew of the bark *Pauline* (of London), of Liverpool, in the county of Lancaster, in the United Kingdom of Great Britain and Ireland, do solemnly and sincerely declare that on July 8, 1875, in lat. 5° 13′ S., long. 35° W., we observed three large sperm whales, and one of them was gripped round the body with two turns of what appeared to be a huge serpent. The head and tail appeared to have a length beyond the coils of about thirty feet, and its girth eight or nine feet. The serpent whirled its victim round and round for about fifteen minutes, and then suddenly dragged the whale to the bottom, head first.

GEORGE DREVAR, *Master*.
HORATIO THOMPSON.
JOHN HENDERSON LANDELLS.
OWEN BAKER,
WM. LEWARN.

Again, on July 13, a similar serpent was seen about two hundred yards off, shooting itself along the surface, the head and neck being out of the water several feet. This was seen only by the captain and one ordinary seaman, whose signatures are affixed.

GEORGE DREVAR, *Master*.
OWEN BAKER.

A few moments after it was seen elevated some sixty feet perpendicularly in the air by the chief officer and the following able seamen, whose signatures are also affixed.

HORATIO THOMPSON.
WILLIAM LEWARN.
OWEN BAKER.

And we make this solemn declaration conscientiously, believing the same to be true, and by virtue of the provisions of an Act made and passed in the sixth year of the reign of his late Majesty, entitled 'An Act to repeal an Act of the present Session of Parliament, entitled an Act for the more effectual abolition of oaths and affirmations, taken and made in various departments of the State, and to substitute declarations in lieu thereof, and for the more entire suppression of voluntary and extra-judicial oaths and affidavits, and to make other provisions for the abolition of unnecessary oaths.' Severally declared and subscribed at Liverpool aforesaid the tenth day of January, one thousand eight hundred and seventy-seven.

GEORGE DREVAR, *Master*.
WILLIAM LEWARN, *Steward*.
HORATIO THOMPSON, *Chief Officer*.
J. H. LANDELLS, *Second Officer*.
OWEN BAKER.

Severally declared and subscribed at Liverpool aforesaid, the tenth day of January, one thousand eight hundred and seventy-seven, before T. S. Raffles, J.P. for Liverpool."

The second and final piece of evidence I shall cite, is that obtained from an article entitled "Strange Sea Monsters," by Mr. R. A. Proctor, which appeared in the *Echo* of the 15th January, 1877. In this communication, Mr. Proctor makes reference to some of the views which I have promulgated on this subject, and by way of illustration, gives the following interesting particulars of a recent sea-serpent narrative :

"Soon after the British steamship Nestor anchored at Shanghai, last October, John K. Webster, the captain, and James Anderson, the ship's surgeon, appeared before Mr. Donald Spence, Acting Law Secretary in the British Supreme Court, and made affidavit to the following effect :

On September 11, at 10.30 A.M., fifteen miles north-west of North Sand Lighthouse, in the Malacca Straits, the weather being fine and the sea smooth, the captain saw an object which had been pointed out by the third officer as 'a shoal!' Surprised at finding a shoal in such a well-known track, I watched the object, and found that it was in motion, keeping up the same speed with the ship, and retaining about the same distance as first seen. The shape of the creature I would compare to that of a gigantic frog. The head, of a pale yellowish color, was about twenty feet in length, and six feet of the crown were above the water. I tried in vain to make out the eyes and mouth; the mouth may, however, have been below water. The head was immediately connected with the body, without any indication of a neck. The body was about forty-five or fifty feet long, and of an oval shape, perfectly smooth, but there may have been a light ridge along the spine. The back rose some five feet above the

surface. An immense tail, fully one hundred and fifty feet in length, rose a few inches above the water. This tail I saw distinctly from its junction with the body to its extremity; it seemed cylindrical, with a very slight taper, and I estimate its diameter at four feet. The body and tail were marked with alternate bands of stripes, black and pale yellow in color. The stripes were distinct to the very extremity of the tail. I cannot say whether the tail terminated in a fin or not. The creature possessed no fins or paddles so far as we could perceive. I cannot say if it had legs. It appeared to progress by means of an undulatory motion of the tail in a vertical plane (that is, up and down).

Mr. Anderson, the surgeon, confirmed the captain's account in all essential respects. He regarded the creature as an enormous marine salamander. 'It was apparently of a gelatinous (that is, flabby) substance. Though keeping up with us, at the rate of nearly ten knots an hour, its movements seemed lethargic. I saw no eyes or fins, and am certain that the creature did not blow or spout in the manner of a whale. I should not compare it for a moment to a snake. The only creatures it could be compared with are the newt or frog tribe.' "*

Placing these two latter narratives side by side with that of Captain M'Quhæ, we may firstly remark the singular coincidence that in all three narratives mention is made of the head of the animal being elevated above water—this feature in the animal's mode of progression having evidently struck the observers as a noticeable point; while the coincidence, viewed as a piece of internal evidence, speaks strongly in favor of the implied truthfulness of the narratives. I think one may fairly assume that the supposition that the parties concerned were deceived into mistaking a lifeless for a living object, cannot for a moment be reasonably entertained. Laying aside for the present all questions as to the zoological position and rank of the animal, we may take it for granted, as based on evidence of reasonable kind, that the "something" seen in each of these cases—which, be it remarked, are but types of many other authenticated records of similar kind—was an active living animal. And we may also affirm that, from the circumstances in which the statements were made, as well as from the character of our witnesses, from their evident desire and from the trouble taken by them to place on record a faithful account of what they had seen, we have ample evidence to prove that part of our second issue which dealt with the question of the living or lifeless nature of the objects seen. If internal evidence is to be trusted at all, the present case strongly exemplifies its worth and value.

We have, however, still to deal with a point in our second proposition, which brings us within the scope of truly scientific inquiry—namely, that devoted to the consideration of the kind or nature of the animals observed by narrators of sea-serpent tales. In the elucidation of this topic we may incidentally discover implied proofs of the correctness and truth of the narratives on which the history of the sea-serpent is literally founded. The discussion of the question from a zoological point of view may be fitly prefaced by an allusion to certain readily explained cases of serpentine appearances caused by well-known and common forms of marine life assuming peculiar attitudes in the water, and of being indistinctly seen by observers. The instance already alluded to, of a shoal of porpoises swimming in line, with their backs and dorsal fins appearing now and then, with a kind of regular alternating motion above the surface of the water, presents an example of a deceptive appearance brought about by a somewhat unusual habit of familiar animals. I well remember being struck with surprise at an unwonted spectacle I beheld in the Frith of Forth some

* It is just possible that the "flabby" or "gelatinous" creature mentioned in this narrative was a giant cuttle-fish, whose manner of swimming, color, absence of limbs, etc., would correspond with the details of the narrative. The "immense tail" might be the enormous arms of such a creature trailing behind the body as it swam backward, propelled by jets of water from the breathing "funnel."

years ago, of an apparently long animal swimming rapidly through the water, and showing several widely detached black fins. Being alone in a small skiff at the time, I confess to the feeling of caution prompting me to restrain my curiosity and to remain at a safe distance from the animal. My curiosity was, however, speedily dispelled by beholding the apparently long and single animal resolve itself into a few sun-fishes (*Orthagoriscus*), which happened to be rolling over and over in the water in line; their motions, viewed from a distance, together with the imperfect glimpse I had at first caught of the animals, rendering my former idea of the presence of an elongated moving body all the more realistic. Such cases are, however, not to be placed side by side with the plain accounts of unknown animals of large size having been distinctly seen in latitudes favoring the growth of animals with which we are less familiar, and to the explanation of the affirmed and verified accounts of which we may next direct attention.

As was naturally to be expected, zoologists began to overhaul their lists on the narration of these tales, with the view of attempting to discover some *known* form which would correspond with the details and appearances observed and described in the sea-serpent accounts. Could the zoologist point with reason to any single form or to a few animals which might, without any undue liberties being taken either with the animals themselves or with the sea-serpent tales, be regarded as the representatives of the marine monsters? Such was the question propounded for the solution of naturalists in former years, and such emphatically is the chief question for consideration in the subject as it at present stands.

The only group of animals to which our attention may be specially directed with the view of finding a zoological solution of the problem, is that of the *Vertebrata*—the highest group of animals, which possesses the fishes as its lowest, and man and quadrupeds as its highest representatives. Laying aside the class of birds as including no forms at all allied to our present inquiry, we are left with, speaking generally, three groups of animals, from the ranks of which various forms may be selected to aid us in solving the sea-serpent mystery. These three groups are the fishes, reptiles, and mammalia, and it may be shown that from each of these classes, but more notably from among the fishes and reptiles, various animals, corresponding more or less closely with the descriptions given of strange marine monsters, may be obtained. An important consideration, however, must not be overlooked at this stage, namely, that too frequently the attempt to reconcile the sea-serpent with some *known* animal of serpentine form and nature, has limited the perceptions and foiled the labors of naturalists. Starting with the fixed idea that the unknown form must be a serpent, and not widening their thoughts to admit of the term "serpentine" being extended to groups of animals other than the reptilia, naturalists soon exhausted the scientific aspect of the subject, and the zoological solution of the problem was almost at once given up. Then, also, as far as I have been able to ascertain, zoologists and other writers on this subject have never made allowance for the *abnormal and huge development of ordinary marine animals.* My own convictions on this matter find in these two considerations, but especially in the last idea, the most reasonable and likely explanation of the personality of the sea-serpent, and also the reconciliation of such discrepancies as the various narrations may be shown to evince. If we thus fail to find in the ranks of ordinary animal life, or among the reptiles themselves, the representatives of the "sea-serpents," I think we may nevertheless build up a most reasonable case both for their existence and for the explanation of their true nature, by taking into account the facts, *that the term "sea-serpent," as ordinarily employed, must be extended to include other forms of Vertebrate animals which possess elongated bodies; and that cases of the abnormally large development of ordinary serpents and of serpent-like*

animals will reasonably account for the occurrence of the animals collectively named sea-serpents.

The case related by Captain M'Quhæ formed, as has been remarked, subject-matter for much discussion. As Mr. Gosse records in his charming work, "The Romance of Natural History," the various suggestions thrown out regarding the nature of the "serpent" seen by the crew of the Dædalus, included and advocated its correspondence with a gigantic seal—this idea emanating from Professor Owen; with a *Plesiosaurus*—an extinct reptile, which possessed a very long swan-like neck, and which attained a usual length varying from eighteen to twenty or more feet; with other and allied forms of extinct reptilia; and with a large species of shark, the basking shark (*Selache maxima*). The idea of Professor Owen does not in the least correspond with Captain M'Quhæ's circumstantial account of the appearance; and to Owen's views the captain contributed a courteous but firm reply, refusing absolutely to admit that his description was susceptible of such modification as would bring Professor Owen's idea of a gigantic seal and the serpent of the Dædalus into close correspondence. Mr. Gosse and others support the suggestion that the animal seen on this occasion was a kind of *Plesiosaurus*. And this idea received apparent support from the fact recorded by Captain M'Quhæ that no motion was observed in the portion of the animal above water; it being thus concluded that the movements were produced by limbs existing in the form of swimming paddles, such as the *Plesiosauri* possessed, and which would in their natural position be concealed below the surface of the water. The suggestion of a huge shark is simply untenable from the utter want of correspondence between any feature of the shark's conformation and the account of Captain M'Quhæ.

The idea that the animal observed in this instance was a huge serpent, seems to have been simply slurred over without that due attention which this hypothesis undoubtedly merits. While to my mind the only feasible explanation of the narrative of the crew of the Pauline must be founded on the idea that the animals observed by them were gigantic snakes. The habits of the animals in attacking the whales evidently point to a close correspondence with those of terrestrial serpents of large size, such as the boas and pythons; while the fact of the animal being described in the various narratives as swimming with the head out of water, would seem to indicate that, like all reptiles, they were air-breathers, and required to come more or less frequently to the surface for the purpose of respiration. The difficulties which appear to stand in the way of reconciling the sea-serpent with a marine snake, in this or in other cases, are two in number. The great majority of intelligent persons are unaware of the existence of serpents of truly and exclusively marine habits; and thus the mere existence of such snakes constitutes an apparent difficulty, which, however, a slight acquaintance with the history of the reptilia would serve at once to remove. Mr. Gosse speaks of these marine snakes—the *Hydrophidæ* of the naturalist—which inhabit the warmer seas, possess compressed fin-like tails adapted for swimming, and are frequently met with far out at sea.* While, as regards the claims of the "sea-serpent" to belong to the true

* It is interesting to note that frequent mention of the occurrence of large "sea-serpents" is made by the crews of vessels which have sailed through the Indian Ocean. An instance of a large sea-snake being seen in its native seas is afforded by the report of the master of the bark Georgina from Rangoon, which (as reported in the newspapers of September 4th, 1877) put into Falmouth for orders on the 1st September. On May 21st, 1877, in latitude 2° N. and longitude 90° 53′ E., a large serpent about forty or fifty feet long, gray and yellow in color, and ten or eleven inches thick, was seen by the crew. It was visible for twenty minutes, during which time it crossed the bow, and ultimately disappeared under the port-quarter. There can be little doubt that this sea-serpent was simply a largely developed marine snake.

serpent order, naturalists have dismissed this idea, simply because it has never occurred to them that a gigantic development of an ordinary species of sea-snake would fully correspond with most of the appearances described, and would in the most natural manner explain many of the sea-serpent tales. Suppose that a sea-snake of gigantic size is carried out of its ordinary latitude, and allow for slight variations or inaccuracies in the accounts given by Captain M'Quhæ, and I think we have in these ideas the nearest possible approach to a reasonable solution of this interesting problem.

It will be asked how I account for the apparent absence of motion in the fore part of the body, and for the existence of a dorsal or back fin. I may suggest, in reply, that the simple movements of the laterally compressed tail, altogether concealed beneath the surface, would serve to propel the animal forward without causing the front portion of the body to exhibit any great or apparent motion; while the appearance of a fin may possibly be explained on the presumption that seaweed may have become attached to the animal, or that the upper ridge of the vertically compressed tail extended far forward and appeared as a fin-like structure.

The most important feature in my theory, however, in which I may be desired to lead evidence, and that which really constitutes the strong point of this explanation, is the probability of the development to a huge or gigantic size of ordinary marine serpents. This point is one in support of which zoology and physiology will offer strong and favorable testimony. There is no single fact, so far as I am aware, which militates in the slightest degree against the supposition that giant members of the sea-serpents may be occasionally developed. The laws which regulate human growth and structure, and in virtue of which veritable "sons of Anak," like Chang the Chinese giant, and the Russian giant, differing widely in proportions from their fellow mortals, are developed, must be admitted to hold good for the entire animal kingdom. There is, in fact, no valid reason against the supposition that a giant serpent is occasionally produced, just as we familiarly observe almost every kind of animal to produce now and then a member of the race which mightily exceeds the proportions of its neighbors. But clearer still does our case become when we consider that we have proof of the most absolute and direct kind of the giant development of such forms as cuttle-fishes, which have thus appeared as if in realization of Victor Hugo's "devil-fish," which plays so important a part in that strange, weird tale, the "Toilers of the Sea." The huge polypus of Pliny; the kraken of Bishop Pontoppidan, which that learned Churchman described as "*similior insulæ quam bestiæ*;" the "poulpe" of De Montfort, which was large enough to swallow a three-decker; and lastly Victor Hugo's cephalopodous creation, were deemed, not so very long ago, to belong entirely to the domain of myth and fancy. A few fragments of cuttle-fishes of large size had been now and then cast up on various coasts, it is true, but these instances were not regarded as at all sufficient to establish the existence of giant members of the group. At the present time, however, we are in full possession of the details of several undoubted cases of the occurrence of cuttle-fishes of literally gigantic proportions—developed, in fact, to an extent justly comparable to that of the supposed "sea-serpent," when the latter is compared with its ordinary representatives of the tropical oceans. An illustration (copied from a photograph) of the head and tentacles of one of these cuttle-fish monsters is annexed (Fig. 3). This creature was cast ashore on the Newfoundland coast, a few years ago. The length of each of the long arms or tentacles coiled round the extremities of the support is twenty-four feet. The eight shorter arms are each six feet in length and ten inches in circumference at the base, and the eyes measured each four inches in diameter. Other giants of the cuttle-fish race are known to science, and no residuum of

doubt now remains in the minds of naturalists regarding the existence of prototypes of Victor Hugo's "devil-fish." Many zoologists might hesitate greatly before assigning these monsters to new genera or species, and would simply regard them as giant developments of ordinary and already known cuttle-fish forms. Is there anything more improbable, I ask, in the idea of a gigantic development of an ordinary marine snake into a veritable giant of its race—or, for that matter, in the existence of distinct species of monster sea-serpents—than in the production of huge cuttle-fishes, which, until within the past few years, remained unknown to the foremost pioneers of science? In the idea of gigantic developments of snakes or snake-like animals, be they fishes or reptiles, I hold we have at least a feasible and rational explanation of the primary fact of the actual existence of such organisms.

FIG. 3.—Giant cuttle-fish's head. The arms, ten in number (two being longer than the others), are represented coiled round a support.

The difference regarding details of appearance and structure described in the sea-serpent tales, leads us next, and lastly, to point out certain considerations which may serve to explain away some of the difficulties which beset the question. That many of the appearances described may have been produced by animals other than true serpents cannot be doubted. It therefore constitutes an important part of our task to indicate the probabilities of various other animal forms "doing duty," so to speak, for sea-serpents on some occasions.

Amongst the fishes we may find not a few examples of snake-like animals, which, admitting the fact of the occurrence of gigantic developments, may be supposed to mimic very closely the appearance of marine serpents. Any one who has watched the movements of a large conger-eel, for example, in any of our great aquaria, must have remarked not only its serpentine form, but also the peculiar gliding motion, which seems frequently to be produced independently of the active movements of the tail or pectoral fin. I do not doubt, however, that a giant eel might by most persons be readily enough referred to its proper place in the animal

sphere, although, when viewed from some distance, and seen in an imperfect and indistinct manner, the spectators—all unprepared to think of an eel being so largely developed—might report the appearance as that of a marine snake.

A visit paid to the Newcastle Museum of Natural History, on which occasion I had the pleasure of inspecting a dried and preserved ribbon or tape-fish of large size, forcibly confirmed an idea that such an animal, developed to a gigantic size, and beheld from a distance by persons unskilled in natural history—and who would, therefore, hardly dream of associating the elongated being before them with their ordinary ideas of fish-form and appearance—might account for certain of the tales of sea-serpents which have been brought under our notice. I had been specially struck with the mention, in several accounts of sea-serpents, of a very long back fin, sometimes termed a "mane," and of a banded body covered with tolerably smooth skin; whilst in several instances the description given of the heads of the sea-monsters closely corresponded with the appearance of the head of the tape-fishes. These fishes have further been described by naturalists as occasionally having been seen swimming with an undulating or serpentine motion close to the surface of the water, the head being somewhat elevated above the surface—this latter feature, as we have observed, forming a remark of frequent occurrence in sea-serpent tales. I found, on making inquiry into the history of these fishes, that their serpentine form had struck previous observers, but, as far I could ascertain, their merits as representatives of sea-serpents had never before been so persistently advocated.

These views and the dimensions of the specimen at Newcastle, I communicated to the *Scotsman* and *Courant* newspapers in June, 1876. The measurements of the ribbon-fish at Newcastle are given as 12 feet 3 inches in length, the greatest depth being 11¼ inches, and greatest thickness only 2¾ inches; the small dimensions in thickness, and the relatively long length and depth, giving to these fishes the popular names of ribbon and tape-fishes. The species was the well-known *Gymnetrus* or *Regalecus Banksii* of naturalists; and by the museum-attendant at Newcastle I was informed that a still larger specimen of the same species was recently obtained off the Northumberland coast, the length of this latter being 13½ feet, the depth 15 inches, and the thickness 5 inches. These fishes possess a greatly compressed body. The breast fins are very small, and the ventral or belly fins are elongated and spine-like. The first rays of the dorsal or back fin are very long, whilst the fin itself extends the whole length of the back, and attains an average breadth of about three inches.

Curiously enough, the publication of these views regarding the ribbon-fishes drew forth from the head of a well-known firm of fish merchants in Edinburgh a remarkable confirmation of the idea that gigantic specimens of these fishes might be occasionally developed. The gentleman in question wrote to inform me that about thirty years ago he engaged the smack Sovereign, of Hull, Baillie commander, to trawl in the Frith of Forth for Lord Norbury, then residing at Elie Lodge, Fifeshire. Whilst engaged in their trawling operations the crew of the Sovereign captured a giant tape-fish, which, when spread out at length on the deck, extended beyond the limits of the vessel at stem and stern. The smack was a vessel of forty tons burthen, and the length may therefore be safely estimated at sixty feet—this measurement being exceeded by the ribbon-fish. The breadth of the fish measured from five to nine inches, and the dorsal fin was from six to seven inches in depth. Unfortunately Lord Norbury seemed inclined to view the giant he had captured with distrust, and ordered the fish to be cut in pieces and thrown overboard; but it is also worthy of remark that the trawlers seemed to express no great surprise at the size of Lord Norbury's specimen,

since they asserted that they had met with one much larger, this latter being colored of a dirty brown hue.

It is interesting to note that the details furnished in the following account —taken from the *Times* of June 14th, 1877—of a marine monster having been seen in the Mediterranean Sea, appear to be explicable on the ideas just mentioned regarding the tape-fishes. The account is furnished by observers whose veracity it would simply be impertinent to question: "The Osborne, 2, paddle royal yacht, Commander Hugh L. Pearson, which arrived at Portsmouth from the Mediterranean on Monday, and at once proceeded to her moorings in the harbor, has forwarded an official report to the Admiralty, through the commander-in-chief (Admiral Sir George Elliot, K.C.B.), respecting a sea-monster which she encountered during her homeward voyage. At about five o'clock in the afternoon of the 2d instant, the sea being exceptionally calm, while the yacht was proceeding round the north coast of Sicily toward Cape Vito, the officer on the watch observed a long ridge of fins, each about six feet long, moving slowly along. He called for a telescope, and was at once joined by other officers. The Osborne was steaming westward at ten and a half knots an hour, and, having a long passage before her, could not stay to make minute observations. The fins were progressing in an eastwardly direction, and as the vessel more nearly approached them, they were replaced by the foremost part of a gigantic sea-monster. Its skin was, so far as could be seen, altogether devoid of scales, appearing rather to resemble in sleekness that of a seal. The head was bullet-shaped, with an elongated termination, being somewhat similar in form to that of a seal, and was about six feet in diameter. Its features were only seen by one officer, who described them as like those of an alligator. The neck was comparatively narrow, but so much of the body as could be seen developed in form like that of a gigantic turtle, and from each side extended two fins, about fifteen feet in length, by which the monster paddled itself along after the fashion of a turtle. The appearance of the monster is accounted for by a submarine volcano, which occurred north of Galita, in the Gulf of Tunis, about the middle of May, and was reported at the time by a steamer which was struck by a detached fragment of submarine rock. The disturbance below water, it is thought probable, may have driven up the monster from its 'native element,' as the site of the eruption is only one hundred miles from where it was reported to have been seen."

I thought the opportunity a favorable one for offering a reasonable explanation of the circumstance, and I communicated my views to the *Times* in the following terms, the latter appearing in that journal for June 15th, 1877: "About a year ago I ventilated in the columns of several journals the idea that the 'sea-serpents' so frequently seen were in reality giant tape-fishes or ribbon-fishes. While not meaning by this statement to exclude the idea that other animals—such as giant sea-snakes themselves—may occasionally personate the 'sea-serpent,' I am, as a zoologist, fully convinced that very many of the reported appearances of sea-serpents are explicable on the supposition that giant tape-fishes—of the existence of which no reasonable doubt can be entertained —have been seen. The report of Captain Pearson, of the royal yacht Osborne, appears, as far as zoological characters are concerned, to be fully explained on the 'ribbon-fish' theory. The long back fins, the scaleless skin, the rounded head, and, lastly, the two great side (or pectoral) fins, each measuring many feet in length, all form so many details corresponding exactly to the appearance of a great tape-fish. I offer these observations with the view of showing that, given a recital founded, as I believe the present narrative to be, on fact, we possess in the lists of living and of well-known animals adequate representatives of the 'great unknown.'"

The imperfect view obtained of the body renders the expression contained in the report, that the body was "like that of a gigantic turtle," some-

what problematical as to its correctness, and in the absence of more defined information, does not necessarily invalidate the views expressed above as to the personality of this strange tenant of the Mediterranean Sea.

In an article entitled "Strange Sea Creatures," which appeared in the *Gentleman's Magazine* for March, 1877, Mr. R. A. Proctor, speaking of my views regarding the sea-serpent, remarks that I offer "as an alternative only the ribbon-fish." This observation being hardly correct, I may point out that in the article in *Good Words*, from which Mr. Proctor quotes my views, I distinctly refer to the probability of giant sea-snakes being occasionally developed and appearing as the modern sea-serpent. The use of the word "only" in Mr. Proctor's remark is misleading; since I offer the ribbon-fishes simply as explanatory of certain sea-serpent narratives, and not as a sole and universal representative of the modern leviathan.

Thus, then, with the ribbon-fishes at hand, and with the clear proofs before us that these and other animals may be developed to a size which, when compared with their ordinary dimensions, we can only term enormous, I think the true and valid explanation of the sea-serpent question is neither far to seek nor difficult to find. To objectors of a practical turn of mind, who may remind me that we have not yet procured even a single bone of a giant serpent, I would point out that I by no means maintain the frequent development of such beings. The most I argue for and require is their occasional production; and I would also remind such objectors of the case of the giant cuttle-fishes which, until within the past few years, remained in the same mysterious seclusion affected at present by the great serpentine unknown. I need only add that I have as firm faith in the actual discovery of the giant serpent of the sea, as that in the giant tape-fish we find its representative, or that in the huge development of ordinary forms we discover the true and natural law of its production.

To sum up my arguments by way of conclusion, I respectfully submit, as does a pleading counsel to his jury—

Firstly: That many of the tales of sea-serpents are amply verified, when judged by the ordinary rules of evidence; this conclusion being especially supported by the want of any *primâ facie* reason for prevarication;

Secondly: That, laying aside appearances which can be proved to be deceptive and to be caused by inanimate objects or by unusual attitudes on the part of familiar animals, there remains a body of evidence only to be explained on the hypothesis that certain gigantic marine animals, at present unfamiliar or unknown to science, do certainly exist; and

Thirdly: That the existence of such animals is a fact perfectly consistent with scientific opinion and knowledge, and is most readily explained by recognizing the fact of the occasional development of gigantic members of groups of marine animals already familiar to the naturalist.

Since the foregoing remarks were penned, details have been published (*Nature*, February 21st, 1878) respecting "A New Underground Monster," which have a very decided bearing on the sea-serpent question, as tending to show that even in the land-fauna of remote districts there may be included animals of a size and nature utterly undreamt of by the scientific world. The details alluded to are forwarded by the well-known naturalist Fritz Müller, and are related of the appearance and doings of the "Minhocao," a creature supposed to be a "gigantic earth-worm," and which inhabits the highlands of the southern provinces of Brazil. The account as given in the pages of *Nature* is of similar nature to the stories told us of the existence and appearance of sea-serpents. There is the same simplicity of narrative, united to an absence of all reason or cause for exaggeration or invention. We are therefore bound, as already remarked, either to accept such stories as true—as relating to observed facts—and to examine them impartially

with the view of detecting discrepancy and of possibly modifying details ; or, on the other hand, to unhesitatingly and simply reject them. This latter procedure would of course be founded on an unwarrantable supposition—such as in the ordinary affairs of life would not for a moment be tolerated—namely, that deliberate lying and meaningless deception are vices of commoner occurrence than humanity at large has been led to suppose. The marks or tracks of the animal, of whatever description it may be, are a valuable source of evidence which, unfortunately, the "pathless deep" cannot offer to the inquirers into the personality of the "sea-serpent." Pending further research, one may only remark that the details given are in all respects of a very circumstantial and clearly related kind, and are such as would lead us to be exceedingly hopeful, now that scientific attention has been directed to the matter, of new and extraordinary additions being made to the lists of zoologists. The following is the account of the animal in question :

"The stories told of this supposed animal," says Fritz Müller, "sound for the most part so incredible that one is tempted to consider them as fabulous. Who could repress a smile at hearing men speak of a worm some fifty yards in length and five in breadth, covered with bones as with a coat of armor, uprooting mighty pine trees as if they were blades of grass, diverting the courses of streams into fresh channels, and turning dry land into a bottomless morass? And yet, after carefully considering the different accounts given of the minhocao one can hardly refuse to believe that some such animal does really exist, although not quite so large as the country folk would have us to believe.

"About eight years ago a minhocao appeared in the neighborhood of Lages. Francisco de Amaral Varella, when about ten kilometres distant from that town, saw lying on the bank of the Rio das Caveiras a strange animal of gigantic size, nearly one metre in thickness, not very long, and with a snout like a pig, but whether it had legs or not he could not tell. He did not dare to seize it alone, and whilst calling his neighbors to his assistance, it vanished, not without leaving palpable marks behind it in the shape of a trench as it disappeared under the earth. A week later a similar trench, perhaps constructed by the same animal, was seen on the opposite side of Lages, about six kilometres distant from the former, and the traces were followed, which led ultimately under the roots of a large pine tree, and were lost in the marshy land. Herr F. Kelling, from whom this information was obtained, was at that time living as a merchant in Lages, and saw himself the trenches made by the minhocao. Herr E. Odebrecht, whilst surveying a line of road from Itajahy into the highlands of the province of Santa Caterina, several years ago, crossed a broad marshy plain traversed by an arm of the river Marombas. His progress here was much impeded by devious winding trenches which followed the course of the stream, and occasionally lost themselves in it. At the time Herr Odebrecht could not understand the origin of these peculiar trenches, but he is now inclined to believe that they were the work of the minhocao.

"About fourteen years ago, in the month of January, Antonio José Branco, having been absent with his whole family eight days from his house, which was situated on one of the tributaries of the Rio dos Cachorros, ten kilometres from Curitibanos, on returning home found the road undermined, heaps of earth being thrown up, and large trenches made. These trenches commenced at the source of a brook, and followed its windings, terminating ultimately in a morass after a course of from 700 to 1000 metres. The breadth of the trenches was said to be about three metres. Since that period the brook has flowed in the trench made by the minhocao. The path of the animal lay generally beneath the surface of the earth under the bed of the stream ; several pine trees had been rooted up by its passage. One of the trees from which the minhocao in passing had torn

off the bark and part of the wood, was said to be still standing and visible last year. Hundreds of people from Curitibanos and other places had come to see the devastation caused by the minhocao, and supposed the animal to be still living in the marshy pool, the waters of which appeared at certain times to be suddenly and strangely troubled. Indeed, on still nights a rumbling sound like distant thunder and a slight movement of the earth was sensible in the neighboring dwellings. This story was told to Herr Müller by two eye-witnesses, José, son of old Branco, and a stepson, who formerly lived in the same house. Herr Müller remarks that the appearance of the minhocao is always supposed to presage a period of rainy weather.

"In the neighborhood of the Rio dos Papagaios, in the province of Paranà, one evening in 1849, after a long course of rainy weather, a sound was heard in the house of a certain Joao de Deos, as if rain were again falling in a wood hard by, but on looking out the heavens were seen to be bright with stars. On the following morning it was discovered that a large piece of land on the farther side of a small hill had been entirely undermined, and was traversed by deep trenches which led toward a bare open plateau covered with stones, or what is called in this district a 'legeado.' At this spot large heaps of clay turned up out of the earth marked the onward course of the animal from the legeado into the bed of a stream running into the Papagaios. Three years after this place was visited by Senhor Lebino José dos Santos, a wealthy proprietor, now resident near Curitibanos. He saw the ground still upturned, the mounds of clay on the rocky plateau, and the remains of the moved earth in the rocky bed of the brook quite plainly, and came to the conclusion that it must have been the work of two animals, the size of which must have been from two to three metres in breadth.

"In the same neighborhood, according to Senhor Lebino, a minhocao had been seen several times before. A black woman going to draw water from a pool near a house one morning, according to her usual practice, found the whole pool destroyed, and saw a short distance off an animal which she described as being as big as a house moving off along the ground. The people whom she summoned to see the monster were too late, and found only traces of the animal, which had apparently plunged over a neighboring cliff into deep water. In the same district a young man saw a huge pine suddenly overturned, when there was no wind and no one to cut it. On hastening up to discover the cause, he found the surrounding earth in movement, and an enormous worm-like black animal in the middle of it, about twenty-five metres long, and with two horns on its head.

"In the province of São Paulo, as Senhor Lebino also states, not far from Ypanema, is a spot that is still called Charquinho, that is Little Marsh, as it formerly was, but some years ago a minhocao made a trench through the marsh into the Ypanema river, and so converted it into the bed of a stream.

"In the year 1849, Senhor Lebino was on a journey near Arapehy, in the State of Uruguay. There he was told that there was a dead minhocao to be seen a few miles off, which had got wedged into a narrow cleft of a rock, and so perished. Its skin was said to be as thick as the bark of a pine tree, and formed of hard scales like those of an armadillo.

"From all these stories it would appear conclusive that in the high district where the Uruguay and the Paranà have their sources, excavations and long trenches are met with, which are undoubtedly the work of some living animal. Generally, if not always, they appear after continued rainy weather, and seem to start from marshes or river-beds, and to enter them again. The accounts as to the size and appearance of the creature are very uncertain. It might be suspected to be a gigantic fish allied to *Lepidosiren* and *Ceratodus*; the 'swine's snout' would show some resemblance to *Ceratodus*, while the horns on the body rather point to the front limbs of *Lepidosiren*, if these

particulars can be at all depended upon. In any case, concludes Herr Müller, it would be worth while to make further investigations about the minhocao, and, if possible, to capture it for a zoological garden!

"To conclude this remarkable story, we may venture to suggest whether, if any such animal really exist, which, upon the testimony produced by Fritz Müller, appears very probable, it may not rather be a relic of the race of gigantic armadilloes which in past geological epochs were so abundant in Southern Brazil. The little *Chlamydophorus truncatus* is, we believe, mainly, if not entirely, subterranean in its habits. May there not still exist a large representative of the same or nearly allied genus, or, if the suggestion be not too bold, even a last descendant of the Glyptodonts?"

SOME ANIMAL ARCHITECTS.

One of the most interesting departments of natural history study is that which devotes itself to the elucidation of the manner in which living beings utilize the various materials of the universe in which they exist, for purposes of protection, for offence or defence, or for food, raiment, and the common necessaries of life. While man, in virtue of his superior powers of adapting himself to his surroundings, may excel lower forms in respect of the variety of means and substances he calls to aid in the advancement of his interest and comfort, it must at the same time be admitted that he is frequently surpassed by the unerring skill with which a particular product is utilized and manufactured by his lower neighbors. Indeed, as a rule, the elegance and quality of the products of animal life at large are found to be apparently out of all proportion to the means by which they were elaborated. And in very many instances the lower animal accomplishes, in the way of direct and unassisted manufacture, a work which man may, after all, but imperfectly imitate by the aid of cunning artifice and mechanical contrivance. The production of a silken thread by the "spinnerets" of the spider or caterpillar is apparently an act of the simplest possible character, viewed in regard to the apparatus and actions which engage in its manufacture; but placed in relation to human contrivance, we may well fail to conceive the delicacy of the spinning-jenny or more modern machine which could evolve a product of like nature. The instinct of the animal, blind and automaton-like as it may be, certainly holds its own in respect of the perfection and results of its work, when compared with the fruits of intelligence, and with the highest exercise of experience and acquired art.

In no phase of their operation do the vital acts and functions of animals present us with greater profusion of detail than in the consideration of the ways and means adopted for the construction of various portions of their bodies from materials derived from the outer world. The power possessed by living beings, not only of laying hold of such materials, but of duly selecting and appropriating such substances as are best adapted to the work in hand, constitutes, after due reflection, one of the marvels of life at large. Nowhere can we see this marvellous power of selection better exemplified than in certain of the lowest forms of animal life, as representing one extremity of the scale of being, and in man as illustrating the highest grade in the ranks of animal society. The waters of our oceans, both at the surface and in their depths, are inhabited by beings of microscopic size, and of a marvellous simplicity of body. Each of these minute animals consists of a speck of structureless, jelly-like substance—the protoplasm or sarcode of the physiologist. Placed under the microscope, these living particles may be seen to live and move, to eat and digest, as do their higher neighbors. Compared with the latter, they may be noted to present singular and paradoxical exceptions to the ordinary rules of living and being, since they are thus observed to live, literally without possessing any apparent structures to carry on the functions of life.

Such are the beings known to naturalists as the foraminifera and the radiolarians (Figs. 4, 5, 6). Between these

FIG. 4.—Shells of foraminifera, all magnified : *a*, *Lagena*, or "flask animalcule ;" *b*, *Discorbina ; c*, *Polystomella*.

two groups no absolute distinction, as far as their living substance is concerned, can be drawn. Yet that distinc-

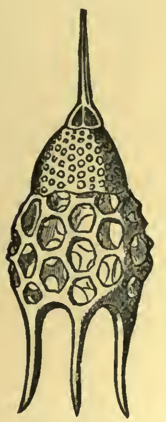

FIG. 5.—A radiolarian shell (*Podocyrtis*).

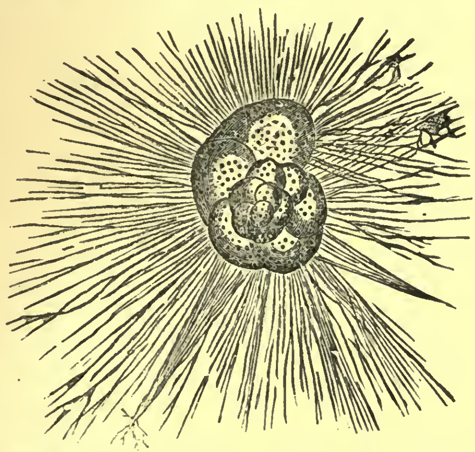

FIG. 6.—A living foraminifer (*Rotalia*), showing the living matter protruded from the shell.

tions may and do exist is perfectly obvious, if we consider the results of the life in each case. The particle of living jelly we term a foraminifer (Fig. 6) takes from the water of the sea a proportion of the lime which exists dissolved in that medium, and from this lime moulds and forms a shell, in which it protects its soft semi-fluid body. The neighbor-particle we name a radiolarian (Fig. 5), existing side by side with the foraminifer, selects flint as its special material from its native waters, and builds a shell of this substance, exhibiting in many cases outlines of mathematical nature, and shapes of the most graceful and elegant kind. Thus there must exist, even in such simple and primitive organisms, not only a selective principle of the exact nature of which we are utterly ignorant, but a further exercise, in the building of a shell, of a power of whose exact direction and extent we know absolutely nothing.

But if the puzzle of life and of animal architecture is so difficult of solution in these lower forms, it is found to present no plainer aspects when offered for investigation in the personality and frame of even the highest being. Regarded from an aspect similar to that in which the denizens of the depths have just been studied, man's existence is seen to comprehend phases of equally puzzling nature. No law of life rests on a firmer basis than that which maintains that the act of living and being is associated with constant change and alteration, and that the wear and tear of life demand proportional repair. Through each tissue of the body, the life-renewing blood is therefore continually being distributed. The muscle, wearied in the actual work of the body, recruits itself from the supply of nourishment thus afforded it ; nerves renew their strength from the same source ; and even thought itself thus becomes related in a distinct manner to the material blood from which the thinking brain derives the wherewithal to carry on its work. Nor is this all. It is not only the case that each tissue derives from the blood the necessary matter to replace that which

has been lost and expended in the work of life. Each tissue, it must be likewise noted, also takes from the common stream of nourishment the materials necessary for the building up of new substance. From the blood, bone selects the materials necessary for the formation of new bone; nerve from the same source gathers matter for the production of new nerve-tissue; muscle therefrom elaborates new muscle; cells of wondrously diverse kind, like buyers of many nations in a common market, select from the blood the special food or pabulum suited to their wants, and therefrom manufacture new cells—in short, the process of growth in man and in all animals of higher grade, exemplifies the results of many varied operations effected by the tissues and organs of the body upon the common material offered to them in the shape of the nutrient blood. How this property of "selection" is exercised, or what is its exact nature, science knows not as yet. But the possession of this remarkable property of selecting and using appropriate material in the actions of life, explain it how we may, constitutes one of the most consistent and clearly defined distinctions which can be drawn between the world of life and the great encompassing universe of non-living matter.

The foregoing remarks may serve to elucidate in some degree the essential nature of a process whereby certain animal forms not only build up structures of massive kind in modern seas, but through which they have been enabled to effect change and alteration of no ordinary extent on our earth, in past epochs of its history. With the coral-animals every one must be familiar as far as the mere name of these beings is concerned; and doubtless few people are unfamiliar with some variety or other of the substance manufactured by the animals just named. As presenting a subject for a brief investigation into some curious phases, not only of animal life but of physical history also, the coral-animal stands possibly without a rival; and as illustrative of a veritable race of animal architects, these beings have no equal, either in respect of the variety or the magnitude of their operations.

Probably no portion of the domain of the naturalist has been more plentifully overrun with error than the special territory which includes the coral-polypes as its tenants. To begin with, errors in the name are of plentiful occurrence; the most common instance of this kind being found in the erroneous designation of "insects" often bestowed on the coral-animals. The name "insect" was no doubt applied in a very loose and general sense in bygone days. But it is the first duty of science to be correct in its nomenclature, and as suggestive of a relationship to the familiar "insect" the use of this term, as applied to the coral-architects, is of grossly erroneous nature. Ere now, also, the fishes of the sea have been credited with the work of building coral-reefs, and the vague term "animalcules" was used in former days to indicate the nature of the workers in coral. Nor have poets been behind in propagating erroneous ideas concerning the nature and work of the coral-animals. As Professor Dana remarks, Montgomery's "Pelican Island" contains statements, which a scientific man at least can hardly excuse on the ground of poetical license. "The poetry of this excellent author," says Dana, "is good, but the facts nearly all errors—if literature allows of such an incongruity. There is no 'toil,' no 'skill,' no 'dwelling,' no 'sepulchre,' in the coral-plantation, any more than in a flower-garden; and as little are the coral-polypes shapeless worms that 'writhe and shrink their tortuous bodies to grotesque dimensions.'" The coral-animals, in short, manufacture or secrete the coral-substance as a part of their life-action and nature, just as a flower manufactures its color, or as a higher animal forms its bones. The living acts of the coral-animal include the formation of coral as an essential and natural duty, and not as a work of a merely accidental or occasional kind.

It is noteworthy that the animal nature of coral was first discovered only

some hundred and fifty years ago. Such an assertion may appear somewhat strange to the ordinary reader; considering the universally admitted animal nature of the substance. But it must be remembered that the distinctions between animals and plants have only in comparatively late years been duly investigated; and the habit of placing reliance upon external form and outward appearance as a means of distinction, certainly tended to place the plant-like and rooted corals as veritable plants before the eyes of naturalists in past days. The appearance of a piece of red coral, or of the nearly allied *Isis* or "mare's-tail" coral, in its living state (Fig. 7), for example, is decidedly plant-like. We see a branching structure, consisting of a hard, central axis of coral, covered with a soft skin or living bark, imbedded in which numerous little beings, each possessing a circle of eight fringed arms or feelers, are to be noted. These little beings are the "coral-polypes." That they are sensitive is proved by their habit of shrinking within the living bark of which they form part, when irritated or alarmed; and as the appearance of the polypes is flower-like to a high degree, it is not surprising to find that the Count de Marsigli should have described and figured the sensitive "flowers" of the coral "plant" in his celebrated work entitled "La Physique de la Mer," published in 1706. The ideas which prevailed at that date regarding the exact structure of the supposed coral "plant," however, were of improved kind as compared with prior conceptions of its nature. Ovid states the popular belief of the classic period when he relates that the coral was a sea-weed which existed in a soft state so long as it remained in the sea, but had the curious property of becoming hard on exposure to the air. Messer Boccone, in the 17th century, was the first to refute this idea, and showed that, although the coral "plant" possessed a soft outer bark, it was in reality a permanently hard structure even in its native waters. It so happened that about 1723 a pupil of Count Marsigli's, Jean André de Peysonnel by name, obtained a commission from the French Academy of Sciences to study the coral "plants" in their native seas. Proceeding to Marseilles and to the North African Coast, Peysonnel soon found reason to alter the views with which he had been indoctrinated respecting the nature of the living parts in the coral. Studying the red coral attentively, this observer said that the coral "flowers" of Marsigli were true animals, and were in fact closely related to the familiar but plant-like "orties" or sea-anemones, which Réaumur in 1710 had shown to be animals. In his remarks on the coral-polypes, Peysonnel compared the coral animals to "une petite ortie ou poulpe." And that the comparison of the coral-polype to the "ortie" or anemone is a perfectly just one, is proved by the fact that the zoologist of to-day selects the latter animals as the type of the great class of coral-producing animals.

Fig. 7.—"Mare's-tail" coral (*Isis hippuris*).

It is no easier task to root out and supplant long-established beliefs in science than in the ordinary affairs of life; and Peysonnel found to his cost that to play the *rôle* of a conscientious observer and reformer is by no means a labor of easy or enviable kind. Réaumur, whose discovery of the animal nature of the sea-anemones might have been supposed to have given him a peculiar aptitude for criticising Peyson-

nel's observations after a just fashion, was one of the first to condemn the young student of Marseilles; and other Academicians followed in the wholesale condemnation of the revolutionary tendencies of Peysonnel's discovery. Disgusted with the treatment shown him by the Academicians whose accredited emissary he was, Peysonnel sailed for the Antilles, engaged in the profession of a naval surgeon, and forwarded to the Royal Society of London the results of his further researches on the coral-polypes. To this day, Peysonnel's observations remain in manuscript in the library of the Natural History Museum at Paris; but it is satisfactory to learn that the ill-treated *savant* lived long enough to find the truth and worth of his discoveries fully admitted. Certain experiments of Trembley, published in 1744, upon those peculiar fresh-water polypes, the hydræ, led to the recognition of these plant-like beings as true animals. The lists of plant-like forms were next overhauled, with the result of demonstrating the animal nature of many organisms which were formerly included within the botanist's domain, and amongst these new-found animals were the coral-polypes, whose exact nature Peysonnel had demonstrated many years before.

The animal nature of the coral-producing beings having thus been demonstrated, their place in the animal series may in the next instance be briefly referred to. As already remarked, the common sea-anemone of our coasts may be selected as the type of the coral-animals—as far as the structure of its soft parts is concerned. The anemones, as every sea-side visitor knows, do not manufacture or secrete any hard skeleton; but if we suppose that such a power existed in these familiar denizens of our coasts, and that, taking lime from the sea-water, they elaborated such material into hard parts of various kind, we should possess a broad but essentially correct idea of the nature of any coral-polype. We thus note the incongruity of applying such a name as a coral "insect" to these animals; whilst we can also realize the justness of Peysonnel's descriptions. The coral-polype is a little lime-secreting anemone, possessing a central mouth surrounded by arms or tentacles, the latter capable of withdrawal on being irritated. Peysonnel's name off "poulpe," also given to the coral-animals, is seen to be equally applicable; this name "poulpe" being derived, like the English "polype," from the Latin "polypus," a term meaning "many-footed." The name "poulpe" or "polype" was also given to the cuttle-fishes—these latter animals, like the anemones and coral-polypes, having numerous arms arranged around a central mouth.

Such being the relations of the coral-polypes to the sea-anemones, certain of the more important differences they exhibit from their familiar representatives may be noted. The common groups of sea-anemones exist, like most other animals, in a single and simple condition—that is to say, each animal is entirely independent of and disconnected from its neighbors. The reverse, however, is the case with the coral-polypes; for among these animals there exists a marked tendency to produce compound "colonies" or aggregated masses of animals, which, curiously enough, originate from single and simple forms by a veritable process of building. Some coral-polypes are, like the sea-anemones, single in their nature. No better example of a solitary coral-polype could be cited than the little Devonshire "cup coral," or *Carophyllia* (Fig. 8), one of the few lingering remnants of British coral-life. The cup coral appears before us as a veritable anemone, possessing the power of elaborating an internal living skeleton; and the foreign mushroom corals or *Fungiæ* may also be cited as representatives of simple corals. The branch of red coral and the vast majority of reef-building and other corals exhibit, however, the true characteristics of their race, in that they are of compound nature, and form, in the reef-building corals, by a process of continuous and connected growth, masses of immense size and extent. Indeed,

it is this feature of constant and connected production which gives to these animals their characteristic power of forming huge monuments of stable and enduring kind on the surface of the earth. It may appear somewhat strange to speak of budding in connection with the animal form. The process, however, not only occurs in the class of coral-polype, but is represented in the nearly allied zoophytes, and in several other groups of animals. The history of a great mass of coral may be thus traced from its earliest stage, when an egg, liberated from some member of an already-formed colony, settled down, attached itself, and produced a single anemone-like polype. This solitary polype next began to bud, and so produced a series of new and connected beings ; and if we suppose the budding process to be in turn repeated by each member of the colony, we can readily understand how the compound organism should attain in due time a growth of almost unlimited extent. Many corals also provide for their increase by a process of *fission*, that is, of simple division of the body-substance into new individuals. The occurrence of this process in the corals is not surprising when we consider that the common sea-anemone may be divided artificially, like the hydra, with the result of producing one or more new individuals. Some of the star corals or Astræas, of the Pacific, grow into great stony hemispheres through this method of increase, these masses frequently possessing a diameter of from ten to fifteen feet. Life and death in the living coral, to use Mr. Dana's words, may be regarded as "going on together, *pari passu.*" As new living parts are developed, the older parts die, but necessarily leave behind their coral-substance to form enduring parts of the mass. In some cases, according to the author just quoted, "a polyp, but a fourth of an inch long, or even shorter, is finally bound at the top of a stem many inches in height. . . . The tissues that once filled the cells of the rest of the corallum have dried away, as increase went on above. . . . The coral-zoophyte may be levelled by transported masses swept over it by the waves ; yet, like the trodden seed, it sprouts again, and continues to grow and flourish as before." Thus the fertility of the coral-polypes may be regarded as of double nature, since we find that each member of a coral colony is capable—first, of giving origin to eggs, each of which when duly developed represents the initiatory stage in the production of a new colony ; and secondly, of increasing each individual colony by an unlimited process of budding or fission.

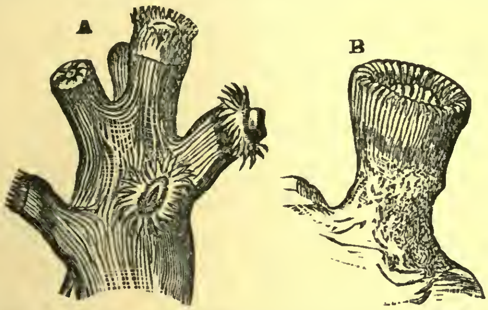

FIG. 8.—Corals. A, *Dendrophyllia*, one of the "tree corals;" B, *Carophyllia*, the "cup coral."

As features in the general structure of corals, which deserve a brief notice by way of conclusion to their personal history, we may refer to the main differences observable in the coral-structure, and to certain variations in the chemical composition of the coral. A piece of red coral, or mare's-tail (Fig. 7), exemplifies one of the two chief varieties of coral ; the coral-substance forming in this instance a solid central axis, on the outside of which

the living bark consisting of numerous polypes is situated. In this and similar cases, all traces of the separate coral-polypes disappear when the living matter is washed away. But in the second variety of coral-structure, well exemplified by the Carophyllia and the great reef-building corals (Fig. 8), the coral-substance is outside the living parts, each little polype being contained within a cell which it has secreted and formed. This latter mode of growth produces the massive solid corals, on the presence and increase of which the formation of reefs depends ; the more delicate and branching species being formed after the type of the red coral and its neighbors. That lime is the chief element represented in the coral-substance may be readily inferred from the preceding remarks. A few corals, however, exhibit a composition in which the lime plays an altogether secondary part. Thus the *Isis* or mare's-tail coral (Fig. 7) of the Indian Ocean and elsewhere, consists of alternate joints of horny and limy matter ; whilst in another group, represented by the *Gorgonias* or "sea-fans," the coral is entirely composed of horny material. The essential details comprised in the general history of the coral-polypes may be briefly summarized by way of introduction to the investigation of their actual work in reef-formation, by asserting each coral-animal to be in all essential details of structure a sea-anemone ; and by the further statements, that the coral-polypes differ from the anemone in respect of their ability to form an internal or external skeleton usually consisting of limy matter, and that they increase indefinitely by a process of budding or of division, and thus give rise to connected colonies. Bearing these details in mind, the further history of the operations of these animals will be readily understood.

Two important points in the life of the coral-polypes demand attention by way of introduction to the general history of their architectural operations. Like all other living beings, the coral animals require certain special conditions as those of their normal existence. In the case before us, the two conditions demanded are a certain *temperature* and a certain *depth* of sea ; these conditions constituting the environments, as it were, of coral life. The question of temperature is a highly important one, inasmuch as the condition of the sea as to warmth will be found to regulate the distribution in space of the corals. The geography of these animals, in short, is bounded by well defined lines or degrees of temperature ; and the statement that reef-building corals will not as a rule flourish and grow in seas the temperature of which falls below 68° Fahr., may be taken as a summary of what has been ascertained on this point. We must, therefore, look to equatorial seas, as those in which the typical development of reef-building corals occurs ; and a ready mode of stating the facts of the distribution of coral life consists in our selecting the equator as a natural centre of our globe, and in measuring off a band of 1800 miles in breadth on each side of that line. A broad band or area some 3600 miles in breadth, encompassing our globe, and having the equator for its centre, will thus be found to include in its course the chief regions of coral growth. But, as Mr. Dana remarks, whilst the distribution of corals depends to a very great extent upon temperature, "regional peculiarities" also "exist that are not thus accounted for."

Whilst the Pacific and Indian Oceans form great repositories of coral-reefs existing within the limits just mentioned, and whilst the Red Sea, the N.E. coast of Australia, and the coast of Florida also exemplify great areas of coral development, certain other oceanic tracts exist from which coral-reefs are wholly absent. Mr. Darwin thus informs us that "no coral-reefs were observed during the surveying voyages of the Beagle on the west coast of South America south of the equator, or round the Galapagos Islands. It appears also," he continues, "that there are none on this coast north of the equator." The western coast of Africa is singularly free from coral-reefs ; and it may

be laid down as a rule of the widest possible kind, that coral-reefs are not found near the estuaries of great rivers, a result clearly due to the mixed or brackish character of the water in such situations. It may be shown that the absence of reefs on the western coasts of South America and Africa is due to the lower temperature which prevails in these areas, but it is possible that other causes—to be hereafter noted—less dependent on temperature or on the sea itself, may more feasibly explain the non-development of coral life in certain regions.

The condition included under the head of *depth* is, if anything, a more important item in the maintenance of coral life and growth than that of heat. If we cite evidence on this point, we may ascertain that the subject of the depth at which corals live received attention from more than one naturalist in past days. The French explorers Quoy and Gaimard, in their report of observations published in 1824, were probably the first who ventilated the opinion that the living reef-building corals existed in *limited depths of sea.* Foster and the earlier navigators assumed that, as coral-reefs were found in depths of literally unfathomable kind, the coral-polypes grew from the abysses of ocean. But Quoy and Gaimard concluded, from observations made in two voyages, that a depth of from thirty to thirty-six feet represented the zone of coral life. Ehrenberg set the limit from which living coral was fished at six fathoms, and Mr. Stutchbury, another observer, maintained that a depth of sixteen or seventeen fathoms might be regarded as the farthest limit of the living reef coral-forming corals. Mr. Darwin concludes "that in ordinary cases, reef-building polypifers do not flourish at greater depths than between twenty and thirty fathoms, and rarely at above fifteen fathoms." And Mr. Dana remarks that "there is hence little room to doubt that *twenty fathoms* may be received as the ordinary limit in depth of reef-corals in the tropics." In answer to a suggestion that "reefs may possibly rise from very great depths through the means of small corals first making a platform for the growth of the stronger kinds," Mr. Darwin says, "this, however, is an arbitrary supposition ; it is not always remembered that in such cases there is an antagonistic power at work, namely, the decay of organic bodies when not protected by a covering of sediment or by their own rapid growth. We have," he adds, "moreover, no right to calculate on unlimited time for the accumulation of small organic bodies into great masses. . . . As well might it be imagined that the British seas would in time become choked up with beds of oysters, or that the numerous small coral-lines off the inhospitable shores of Terra del Fuego would in time form a solid and expansive coral reef."

The causes of the limitation in depth of corals may be summed up by recognizing the necessity of a due supply of light and air for maintaining the vitality of the living animals. The living polypes require light as a condition for the exercise of their vital functions, and they no less imperatively demand a due supply of the vivifying oxygen ; these essentials for vitality being obtainable only in surface-waters, or within a limited depth in the ocean. Recognizing the settled and affirmed nature of these two conditions of coral life, we may next proceed to examine the curiously complicated problem which the condition of limited depth especially imposes upon the naturalist. How, in other words, when we take into account the limitation in depth of living corals, can we explain the creation of coral-reefs and islands existing in abyssal or unfathomable depths of sea?

It is a striking characteristic of scientific procedure that no new or strange fact is long left without an explanation. That the first explanation may not necessarily be correct, but is, on the contrary, more likely to prove untenable when a wider knowledge of the fact or facts is obtained, are statements which the history of scientific hypotheses and their verification fully indorses, and which the fate of the first-offered theo-

ries of the erection of coral-reefs fully confirms. To appreciate the points which the theories of the erection of coral-reefs include, it becomes necessary to glance, in the first instance, at the various forms which coral-reefs may assume. These reefs may be divided into fringing reefs, barrier reefs, and atolls or lagoon reefs. The nature of the first-named erections is explained by their name. They simply fringe or skirt the margins or coasts of lands, and appear to be mere coral-extensions of the ordinary beach. A typical reef of this description is seen to surround the island of Mauritius, and another skirts the coast of Cuba. A sounding-lead allowed to descend on the seaward face or edge of a fringing reef would strike the true sea-bottom at a depth not exceeding twenty-five fathoms. Its outer edge is formed of true reef-building corals, which seem to thrive best amid the spray and surf. Near the shore, different and less hardy corals live; and in the shallow water which intervenes between the reef and the shore, a whitish mud, consisting of the *débris* of the dead corals, is found, together with the blocks of coral which have been torn from the reef and cast up on the shore by the violence of storms. "A fringing reef," says Mr. Darwin, "if elevated in a perfect condition above the level of the sea, would present the singular appearance of a broad, dry moat, bounded by a low wall or mound." The breadth of a fringing reef depends on the slope of the beach; the more gradual the slope, the farther seaward will the reef extend; whilst a steep beach, preventing a great depth of water nearer the shore than the sloping form, will proportionally limit the seaward growth of the corals. On very steep coasts, fringing reefs may not exceed fifty yards in width, that measurement representing the distance from the shore at which the coral-polypes reach their farthest limit of depth.

The barrier reef is an erection of a very different kind from the preceding variety of reef. In its most typical form, well seen on the north-east coast of Australia, or on the western coast of New Caledonia, a barrier reef appears as a great bank or reef of coral, separated from the adjoining land by a belt of water named the "inner channel." Sometimes an island—like Tahiti—is surrounded by a barrier reef, which stands like a great wall around the land, but is separated from the latter by a channel. In the latter case the barrier reef receives the appropriate name of "encircling reef." Some of the barrier reefs are of immense extent. The great barrier reef on the north-east coast of Australia extends uninterruptedly for 1000 miles, and nearly in a straight line, and varies from ten to ninety miles in breadth. If transferred to European seas and extended round European coasts, this reef would reach from Brest across the mouths of the Irish Sea and English Channel, round the western coast of Ireland to Iceland; whilst if extended in another direction, it would pass round the coasts of Scotland and the Shetland Isles, and terminate on the Norwegian shores. Soundings taken on the seaward face of a barrier reef reveal immense depths and a state of matters very different from that existing in the fringing reef. The seaward aspect of the latter was seen to exist within the limit of depth of the coral-polypes. The barrier reef, on the contrary, is found to rise from depths altogether beyond the sphere of coral life. And whilst the face of the fringing reef is covered with living coral, that of the barrier reef possesses a living incrustation only in its upper part, and to a depth of 100 feet or more; all its substance below this limit consisting of dead coral.

The third variety of reef is named the atoll or lagoon reef. This latter form of reef exists as a more or less circular ring of coral of varying breadth, inclosing a sheet of still water—the lagoon. These coral islands are common in the Indian and Pacific Oceans. Keeling or Cocos Atoll, in the former ocean, measures 9½ miles in its greatest width. Bow Island is 30 miles long and 6 miles wide; whilst in the Maldive Archipelago, atolls of very large size are met with; one island meas-

uring 88 geographical miles in length, its greatest width being under 20 miles, and its least width 9½ miles. Beholding a great coral ring, bearing on its surface a low island soil with vegetation, and protecting a quiet lake-haven from the restless ocean without, it is little to be wondered at that the earlier voyagers recorded their surprise that the apparently insignificant architects of such an erection are able to withstand the force of the waves and to preserve their work amid the continual attacks of the sea. Pyrard de Laval, writing in 1605, well remarks, "It is a marvel to see each of these atollons surrounded on all sides by a great bank of stone—walls such as no human hands could build on the space of earth allotted to them. . . . Being in the middle of an atollon, you see all around you this great stone bank, which surrounds and protects the island from the waves; but it is a formidable attempt, even for the boldest, to approach the bank and watch the waves as they roll in and break with fury upon the shore." Soundings on the seaward side of an atoll reveal abyssal depths as in the case of barrier reefs; and, as in the latter instance, the living corals exist only at the surface margins of the reef, extending downward merely to their natural limit of depth. The massive living corals, as before, flourish best where the surf is of the heavest description, whilst more delicate kinds grow within the quiet waters of the lagoon; and it must be borne in mind that the living corals, of whatever variety, require to be constantly immersed in their native waters. Exposure, even for a limited period, to the rays of the sun, is fatal to their vitality. From this observation it becomes clear that the labors of the coral-polypes are inadequate to raise the reefs above the surface of the water; other agencies, as will be presently noted, completing the erection, by the addition of foreign matter for the elevation of the reef. The depth of the central lagoon varies, a depth of forty-nine fathoms being of maximum kind; and the bottom of this central lake consists usually of sand and soft clay, or fine calcareous mud, the latter resulting from the grinding-down process to which the coral is subjected by fishes and other enemies. The coral ring of the atoll is broken at one or more points by an opening, often large enough to admit the passage of large ships into the quiet haven within. This passage into the lagoon invariably occurs on the leeward aspect of the atoll; this fact possessing a practical interest for the navigator who has succeeded in safely avoiding the dangerous swell and surf of the seaward side.

Noting these three varieties of coral-reefs, we may now proceed to inquire into the chief theories which from time to time have been constructed with the view of explaining their mode of formation. Just as the nature of the coral itself formed, as we have seen, a subject of debate amongst the earlier writers, so the "reason why" the coral-polypes aggregated themselves together in the form of atolls and barrier reefs, constituted one of the knotty points of early biological science. The same mysterious "instinct," which was supposed to be the cause of their secreting lime, was credited with being the directing impulse in causing the selection of admirable sites for the coral-reefs. They formed a great protecting reef, according to Flinders, that they might work in safety under its shelter, and that the leeward aspect of the reef might form a kind of nursery-ground, whence "their infant colonies might be safely sent forth." In this case the coral-polypes are credited with the possession of intelligence of no mean order, and are presumed to co-operate together for an end and in a manner utterly unknown to be represented in any other group of animals. Such a theory, moreover, leaves untouched the essential question of the causes in virtue of which coral-reefs should assume the characteristic forms observed in the atolls and barrier reefs, and the want of an explanation of the latter points suggested a theory whose simplicity is unfortunately its only recommendation. It was believed that, taking into account the imitation

in depths of living corals, these animals obtained a basis and foundation in land which lay submerged some 120 or 150 feet in the sea ; so that every coral-reef was regarded as simply presenting us with a coral top to solid land. The circular form of the atoll was ingeniously accounted for on the supposition that the coral-polypes had built around the rim of a volcanic crater, and that the break in the coral ring affording entrance to the lagoon was represented by a fissure of greater or less extent in the continuity of the crater's margin. The plausibility of this theory becomes sadly weakened if we subject its supporters to the cross-examination of the physical geographer. For the stability of the ideas thus ventilated, it would require to be proved firstly that submarine plateaus or ridges existed not only in great profusion in the coral regions, but also that these plateaus existed at a uniform depth, so as to afford the necessary basis for the operations of the polypes. That physical geography affords not the slightest justification or foundation for such a belief, is a fact known to every school-boy ; and now that we are tolerably familiar with the nature of the bed of more than one great ocean through recent sounding and dredging expeditions, this theory might be simply relegated to the limbo of impossible beliefs on the ground of its entire inconsistence with plain fact.

But its improbability might also be argued from the fact of its assuming the existence, in the coral areas of the ocean, of sunken land, which could not —except on the most arbitrary of suppositions—be supposed to be limited to these areas alone. And as other ridges of land within 150 feet of the surface are unknown in other seas and areas, the theorist would have to explain the singularity of submarine plateaus existing so plentifully in one region and their entire absence in another. Geological science, if appealed to in this matter, would own that it knew of no support which could be given to the assumption of local elevations in the sea-bed ; whilst it would suggest that the levelling tendency of the waters of the sea in smoothing down the ocean-bed would weigh greatly against the theorist's views. Thus, if the existence of submarine ridges be disproved, this first theory must necessarily fall to pieces and be wholly put out of court. The suggestion that atolls exist on a volcanic foundation meets with a similar fate when tested by the facts of geology and the logic of common-sense. It may thus be remarked, that the mere shape and configuration of many of the atolls is entirely inconsistent with this explanation, no volcanic crater possessing, for instance, the form of Bow Atoll, " which is five times as long as it is broad." And the mere question of size is at once seen to prove the utterly untenable nature of the suggestion of the origin of atolls. Since it might be asked if reason could support a theory which on its own showing must postulate the existence of a volcanic crater eighty-eight miles long by twenty miles broad at its greatest width, the latter being the measurements of one of the Maldive atolls. As in the previous case, this theory demands the recognition of the existence of numerous volcanic chains all existing within a limited depth of the surface ; and, in view of the utter want of evidence to show that any such immense volcanic area ever existed, this supposition must be unhesitatingly rejected. One further idea emanating from Chamisso may be lastly noted. This author held that, as the reef-building corals love the surf, the outermost parts of the reef will tend first to reach the surface and so assume a circular form. But this idea assumes that the foundations of the reef in such a case consist of a flat bank, and the existence of such foundations is, as we have already noted, inconsistent with fact. The origin of barrier reefs did not receive from the naturalists and geologists of the past the same amount of attention as the question of the nature and origin of the atolls—a result due to the apparently more recondite character of the latter problem. The great Australian barrier reef was alleged to be founded " on the edge of the submarine precipice parallel to the shore."

This idea may be dismissed with the remark that no evidence is afforded that any such precipice or plateau exists.

It may be affirmed that until the year 1842 no theory of the origin of coral-reefs which stood the test of scientific cross-examination was promulgated. In that year Mr. Darwin gave to the world his views on this subject, and enunciated a theory which has firmly stood its ground against the most severe examination and criticism, and which at the present time remains as the only feasible theory of the origin of coral-reefs. If it be taken as a test of the truth of a hypothesis that it intelligently explains all the facts of a case and is found to be inconsistent with none, then Mr. Darwin's ideas may be regarded as constituting a theory of the most perfect kind. And it may be fearlessly affirmed that, had Mr. Darwin accomplished no further investigation than his researches on coral-reefs, he would have been entitled to the admiration and gratitude of all who regard the advancement of knowledge as of supreme consequence to man's welfare. Mr. Darwin spent some five or six years of his life (1831–36) as naturalist on board H.M.S. Beagle under Captain Fitzroy, and was thus enabled to study the coral-polypes and their work in the most direct and advantageous manner; whilst Mr. Dana, representing the scientific leader of an American circumnavigating expedition (1838–42) under Captain (now Admiral) Wilkes, may be regarded as an authority of equal rank with Mr. Darwin on the subject of coral-reefs. It is worthy of remark that, whilst Mr. Darwin's observations were published in 1842, Mr. Dana's report on coral-reefs was then in manuscript, but the conclusions at which these observers arrived, independently of one another, were of essentially identical kind, and the fact speaks powerfully for the implied correctness of the views promulgated by these explorers. Mr. Darwin's theory, besides offering a consistent explanation of all the facts of coral life, serves in the most direct manner to correlate and connect in the most natural fashion the various forms of coral-reefs. Starting with the assumption, already seen to rest on the most solid evidence, that coral life is limited to 150 feet as a maximum depth, Mr. Darwin rests his theory of the origin of reefs on the fact that land subsides.

The recognition of the geological phenomena known as the subsidence or sinking of land forms the key-note of Mr. Darwin's views; and it may therefore be viewed as a pardonable digression, if the nature of these phenomena is in the present instance briefly explained. That land rises and sinks is a fact well known to the geologist, who can point to many areas of the earth's surface in proof of his statement. Every one conversant with the elements of geology knows that the majority of the rocks composing the crust of the globe have been formed under water, and that a process of elevation must be assumed to account for their present position. Thus, true chalk is a rock composed of the remains of the minute foraminiferous shells already noticed. The cretaceous rocks were deposited in the sea-beds of the past, just as the shells of modern foraminifera fall to the bottom of existing oceans to form a chalky layer which may be destined, when elevated, to form the chalk of the future. Elevation of the earth's surface thus exists as a primary fact of geological science. But it may be conclusively shown that, whilst at the present day certain areas of our earth's surface are undergoing this process of upheaval, other areas as surely exhibit an opposite or subsiding tendency. The fact that land subsides must, however, be regarded in the light of the obvious relations which exist between the sea and the land. The subsidence of land is ascertained and calculated by its fluctuations as regards the sea-level. Hence it is necessary that the burden of the change should be laid upon the shoulders of the land, and that the sea should be shown to be a factor of constant and unvarying nature in this process. That the water of the ocean obeys the same laws

as the fluid in a vessel, is a stable fact. Practically, we may regard the sea-level as invariable ; and although the theories of the influence of a polar ice-cap as tending to disturb the oceanic equilibrium are not wanting, such widely operating causes, even if proved to exist, would affect areas of so wide an extent that their influence would be of the most slight and meagre kind. On the contrary, where the changes between the level of land and sea are of a markedly local description and limited to a certain defined area, the alteration is clearly seen to have its seat in the land and not in the sea, the level of which, outside the defined area of change, can be shown to be absolutely unaltered. For example, on the coasts of Devon and Cornwall the remains of submerged forests are met with, the roots of the trees being still fixed in the soil. As these trees must have grown on land, it follows that the incident reveals the submergence of a land-surface. If we credit the sea with having risen, and suppose that the land has been stationary, we must be able to show not only that the whole southern coast of England has been similarly invaded by the sea, but that the opposite coast of France, and all the coasts bordering the North Sea and Atlantic, have been inundated. It is needless to point out that no such evidence is forthcoming, and that we are dealing with a subsidence of land, and not with a rising of the sea. Ample evidence of the existence of large areas of land subsidence is afforded by the geological survey of the southern coasts of Sweden ; the lower streets of the seaport towns of Scania, formerly inhabited, being now under water. The coasts of Greenland are similarly being depressed, and very marked alterations in climate may be shown to result from the existence of these movements on the part of what can no longer be regarded as the " stable land."

Bearing in mind the fact that land may subside completely beneath the surface of the sea, we may return from this necessary digression to the consideration of Mr. Darwin's theory of coral-reefs. Beginning with the fringing reef, well seen in the island of Mauritius, it is shown that such an erection forms the initial stage of coral-formation. Here we find a natural foundation for the work of the living coral-polypes ; the animals having fixed on a natural coast-line, and having, at a suitable depth for themselves, constructed a belt or fringe of coral, the seaward depth of which, as we have seen, does not descend below the fifteen-fathom line. So long as the land skirted by the fringing reef remains stable and stationary, so long will the reef remain essentially in its primitive condition. According as the shore slopes abruptly or gently, so will the breadth of the reef be limited, or be extended out to sea. No increase in depth is possible, seeing that the polypes have already attained, or have built upward from, their lowest depth ; and if the land remains in the condition in which it was when the fringing reef was first formed, the latter erection will also remain *in statu quo*. But, in accordance with the evidence of the geologist, land may sink. If we suppose that the land on which a fringing reef has grown slowly subsides, changes of great extent may be shown to occur within the attached zone of coral life. The lowermost corals, being carried out of their depth, must of necessity die ; a new sphere of operation being at the same time afforded by the subsiding operation for the uppermost corals. These latter will therefore continue to produce new polypes, and an upward growth of the coral will accordingly accompany the downward movement of the land. If the land-subsidence continues, the increase of the sea-wall or outer aspect of the reef will be greater than that of its shore side or inward portion, seeing that on the former surface the conditions of life are more suitable for the growth of the massive reef-building corals. The inner part or shore aspect of what was once the fringing reef thus becomes deeper and deeper as subsidence proceeds, and in due time we find a great coral-ridge growing up in front of the sinking land, and separated therefrom

by a belt of deep water. In this way the barrier reef is evolved by the subsidence of the fringing reef. But the land may be depressed to a still greater extent, and as before, the upward coral-growth will keep pace with the subsidence. If we suppose that we are dealing with the case of an island or with land of limited extent, we may conceive that in time the last island peak or surface of original land will sink beneath the waves. The coral-growth has, however, been proceeding uninterruptedly as before ; and the lost land becomes ultimately surrounded by a great wall or cup of coral, inclosing a quiet lake—the atoll or lagoon of the Pacific voyager.

The formation of coral-reefs may be readily understood from an inspection of the appended theoretical figures (Figs. 9 and 10), by the late Mr. Jukes. The sea-levels are represented at S S ; and in the first figure A B and C D are two shores sloping seaward at different inclinations or angles. On these shores corals grow at their own limited depth, represented by the line F F, and thus form a fringing reef (R E G). The greater growth of the reef at E G, that is, farthest from the land, may produce a sheet of water between R and E ; and the breadth of the reef is seen to be greatest where the sea-bed slopes least abruptly. If the shores (A B and C D) begin to subside, the sea will flow upon the land, and the width of the reef (R E) will be increased, especially on the outer face (E G) by the upward growth of the coral, so that in time the belt or sheet of water between R and E becomes of considerable extent, and a barrier reef is formed. In the case of land of limited extent, the formation of an atoll readily takes place as represented in the second figure. The various lines (S S) represent the unaltering sea-level. The shaded central portion represents the original land. The letters B B indicate the successive upward growth of the coral as the land subsided ; and as the land disappears in the deep it becomes an atoll (A A), surrounded by a great wall or cup of coral-structure.

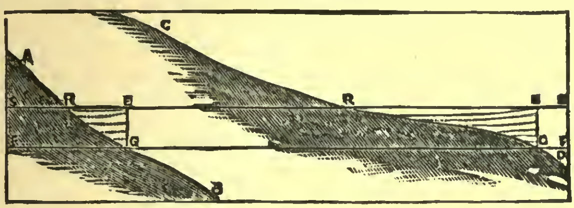

FIG. 9.—Diagram of coral-reefs (Jukes) : A B, fringing reef ; C D, barrier reef.

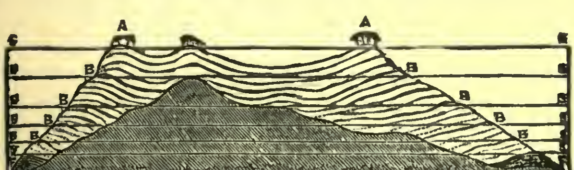

FIG. 10.—Diagram of atoll or lagoon reef (Jukes).

The final processes which the atoll undergoes consist in the filling up of the lagoon by *débris* derived from the reef, and in the formation of a soil on the coral-ring by the action of the sea, which detaches fragments of coral-rock, and heaps up sand on the surface of the new land. The sea will drift its weeds on the coral-rock, and these will decay and form a fertile soil in which seeds carried by the winds will take root and grow ; and ultimately some race of nomads may be found to colonize this strange sea-born land. Thus we observe that a fringing reef affords evidence of either the rising or stationary character

of its land; the barrier reef clearly intimates the subsidence of its foundations; and the atoll exists as an enduring monument erected over the burial-place of old and forgotten territory.

Such being Mr. Darwin's views, the feasibility of his theory may be proved by an appeal to the facts and deductions of geological science in particular. First, is it capable of proof that the regions in which the atolls and barrier reefs mostly abound constitutes areas of land-subsidence? One vast area of this kind, extending in the Pacific Ocean for 7000 miles from Pitcairn's Island and the Low Archipelago to the Caroline and Pellew Islands, is a region wherein the work of coral-erection proceeds apace; and between India and Madagascar another area of depression measuring 1500 miles in length has been clearly mapped out. A counter-proof of the correctness of Mr. Darwin's views is afforded by the deductions of geology in ascertaining that movements of elevation and depression in the earth's crust do not proceed contemporaneously in the same area; the causes producing the one movement being opposed to those which give origin to the other. Thus volcanic force invariably tends to produce elevation of the earth's crust, and the geologist would therefore esteem it a proof of the correct nature of Mr. Darwin's theory, could it be shown that active volcanoes were absent from the areas in which atoll and barrier reefs exist. Mr. Darwin's reply to this criticism is illustrated by an elaborately prepared map of the distribution of volcanoes, and may be given in his own words. It may "be considered," he says, "as almost established, that volcanoes are often present in the areas which have lately risen or are still rising, and are invariably absent in those which have lately subsided or are still subsiding;" whilst he has conclusively shown that the areas of active coral-formation exist as regions destitute of active volcanoes, and in some instances as areas possessing no volcanoes at all. "The regions occupied by fringing reefs may be said to be those in which volcanic matter every now and then bursts forth," and tends to elevation. The areas of barrier reefs and atolls are "wide spaces sinking without any volcanic outbursts; and we may," concludes Mr. Darwin, "feel sure that the movement has been so slow as to have allowed the corals to grow up to the surface, and so widely extended as to have buried over the broad face of the ocean every one of these mountains, above which the atolls now stand like monuments marking the place of their burial."

These ideas are strongly supported by the observations made on *raised* coral-reefs. That sinking must take place in the course of the formation of reefs is proved by the examination of some raised coral-rocks, "as at the island of Mangaia in the Hervey Group," where the elevated reef rises 300 feet above the sea-level. These rocks must have been formed in water; and as we know the limit of coral life to have been 150 feet, it follows that such elevated reefs could not have been made "without a sinking of many scores of feet during their progress." Another explorer tells us that he can vouch for the existence of raised coral-reefs at Timor and Java, these coral-rocks existing at heights varying from 100 to 200 feet above the level of the sea.

The subject of coral and coral-reefs, like most other studies in natural science, becomes related in an intimate manner to other branches of knowledge, and to other trains of thought. In the case before us, it may prove interesting if, by way of conclusion, we endeavor to point out one of the many subsidiary subjects on which a study like the present is adapted to throw some degree of light. The most sublime idea of nature which man can well obtain is that of the uniformity and constant character of natural operations and laws. To the student of nature, the idea of capriciousness exists only as the result of an erroneous interpretation of some violated course of law and order; and in the modern study of earth-science the geologist is led to recognize in the principle of the uniform-

ity of nature the means whereby all physical actions are bound together in one harmonious whole. It so happens that the evidence capable of being adduced from the growth of coral-reefs goes far to prove the constant and uniform state of our earth throughout immense periods of time. The testimony of Mr. Dana with regard to the rate at which coral grows is to the effect that the massive corals on which the increase of reef depends are of very slow growth ; the branching and certain other kinds growing at a faster rate. One-eighth of an inch per year is given by this author as " the average upward increase of the whole reef-ground per year ;" and the estimate appears to be a perfectly just one, when judged by the evidence afforded us of the rate of growth in corals. All authorities agree in stating the growth of massive corals at a very low rate, and the time which has been occupied in the formation of a reef 2000 feet thick must, therefore, on Mr. Dana's estimate, be set down at 192,000 years. This computation, it must be remembered, is one dealing with the work of modern corals. In the far-back past, coral-reefs existed similar in every respect to their modern representatives ; these fossil reefs in many cases evincing an immense thickness. Hence we are led to believe that, notwithstanding the alteration which our earth has undergone, it has had prolonged periods of rest ; and the existence of a modern coral-reef may therefore afford evidence, not only of the immensity of past time, but also of the uniformity of nature's ways and works during periods compared with which the farthest limits of history and even of man's own age are but as yesterday. The deductions from a study like the present may be fitly expressed in Laugel's words, as giving us " a higher conception of the universe than that entertained by the ancients ;" since science " no longer regards the material world as the plaything of mere caprice," but " embraces the past, the present and the future in a magnificent unity, outside of which nothing can exist."

PARASITES AND THEIR DEVELOPMENT.

If man is to be regarded as the favored child of Nature, and if it be held as true that life at large is subservient to his sway and rule, it is no less true that he is liable to suffer severely from the attack of certain of his lower neighbors, and that he is despoiled in various fashions by some of the most insignificant of living beings. Insects of various kinds, insignificant as to size, but powerful beyond comprehension in virtue of their numbers, devastate the crops which exercise his mind and appliances in their cultivation. And after the crops have been fully stored and garnered, the labor of months and the full fruition of the farmer's hopes may be destroyed by the insidious attack of granary-pests. Plants of lowly grade—minute fungi and like organisms—personally known to the microscopist alone, blight at once the prospects of the agriculturist and of his cereals. A minute fungus, burrowing its way within the tissues of the potato-plant, has ere now brought destitution and famine on a nation, and still causes disease amongst our tubers to an extent which none but our potato-growers can fully realize. Nor is the farmer's sphere singular in respect of its liability to the attack of animal and plant foes. Parasites, the complexity of whose life history almost defies belief, invades the stock of the breeder of cattle and sheep and decimate his flock ; whilst these same parasites may occasionally invade the human domain itself, and cause disease and death to prevail to an ala ming extent. Hidden enemies in the sea burrow into the sides of ships, or undermine man's piers and bulwarks. Poison-traps lie in wait for human footsteps ; and claw and tooth are as ruthless when opposed to humanity as when prepared to attack lower life. Speaking generally, therefore, man may be readily shown to be by no means the undisputed " monarch of all he surveys " in the territory of either botanist or zoologist ; and the province of mind and intellect may be invaded by foes against which man may find it

impossible to contend. Much has been done, it is true, in the way of repressing many of our lower enemies, and the increase of scientific knowledge has had few triumphs of higher kind than are witnessed in those researches which have exposed the nature of our animal and plant enemies and shown us the steps necessary to be taken for their annihilation. But the field of inquiry seems well-nigh boundless ; and it should certainly form one of the most powerful arguments in favor of the study of natural science, that on the advance in our knowledge of economy, botany, and zoology the prosperity of our commerce and the conservation of our health may be shown largely to depend.

Perhaps one of the richest fields of research in the way of repression of our lower enemies, is offered by the life-history of some of the most common parasites which decimate our flocks and herds, and which, as already remarked, occasionally invade the human territory itself. Well does the shepherd know the symptoms of "rot" in his flock, and anxiously does he apply to the veterinarian for advice in his extremity. His sheep, in such a strait, present a dull and dejected appearance ; they are "off their feed," he will tell the observer ; and are in a thoroughly emaciated condition, despite the shepherd's kindly care and supervision. By-and-by deaths will begin to be of frequent occurrence, and when the dead subjects are carefully inspected the cause of the disorder is not hard to discover. The body of the affected sheep exhibits a state of thorough disorganization, and when the liver is carefully inspected, hundreds of small flattened bodies, each about three-quarters of an inch long, are found within the bile-ducts ; whilst in the bile itself thousands of small particles are to be discovered by microscopic aid. The small flat bodies are "flukes" (Fig. 11), and the particles are the egg of these animals. What, it may be asked, are these flukes, which, according to trustworthy evidence, carry off annually between one and two millions of sheep at the very lowest computation? The reply to this question is readily given. The "liver-fluke" is one of a group of internal parasites

FIG. 11.—Liver-fluke, or *Fasciola*, magnified.

which has been known from comparatively early times. It was certainly known in 1547, and was lucidly described in 1552 by an author who was shrewd enough to attribute to its presence an epidemic which decimated the flocks of Dutch farmers in that year. Its "area of distribution," to use a scientific but expressive phrase, is not confined to sheep alone, but includes cattle, the horse, hares and rabbits, the spaniel, deer and antelopes, and even man himself. A little flat and somewhat oval body, with a tree-like arrangement of tubes for a digestive system, and possessing a couple of suckers for adhesive purposes—such are the main features which a liver-fluke presents for examination. A more innocent-looking animal could hardly be found, and the cause of its injurious effects upon its animal hosts might remain a mystery, did our inquiries cease with the investigation, so to speak, of its *personnel*.

A highly important consideration, however, and one which extends beyond the restricted domain of our present subject, is that which recognizes in *numbers* and *time* two important factors in elevating agencies of apparently unimportant kind into forces of vast or uncontrollable nature. The rain-drop is insignificant regarded merely as a particle of water, no doubt ; but multiply your rain-drops indefinitely, and you obtain the agent which will wear

the hardest rock, excavate the giant cavern, or form the foaming cataract with strength to sweep away the greatest obstacles man or nature may oppose to its fury. Invest, further, the idea of the single rain-drop with time, and the action which appears feeble, if viewed for a single moment, becomes of mighty extent when multiplied into years and centuries. And similarly with the case of the fluke and its neighbor-parasites. A single fluke is of itself an unimportant quantity, but when this quantity becomes multiplied by hundreds, the proverb that "union is strength" receives a new and very decided application. Existing in large numbers within the liver-ducts of the sheep, the flukes cause irritation, and a whole train of symptoms which end usually in starvation and death. Hence the extreme fertility of parasites might well afford a text whereon a sophist might inveigh against the wise regulation of the domain of living nature, were it not that in reality these animals are checked and controlled through the actual complexity of their own development. Strange as the statement may seem, it is nevertheless true that Nature appears to offer a premium against the development and increase of these and other parasites, through their having to undergo a series of very striking changes on the way to maturity. The parasite's path to adult life may truly be described as chequered in the highest degree. There are numerous pitfalls and snares laid for its reception, and for the extinction of its young life; and the "struggle for existence" in the present case is not only fierce, but, in the case of a very large majority of the combatants, utterly hopeless.

Let us briefly trace the life-history of a fluke by way of practical illustration of these latter remarks. From each individual fluke residing within the body of its sheep-host, hundreds of eggs are discharged. Each egg undergoes a preliminary process of development, and from the eggs which escape into water, little free-swimming bodies are liberated. These minute living particles are young or embryo flukes Each resembles an inverted cone in shape and swims rapidly through the water by aid of the microscopic filaments which fringe its body. It is clear that such eggs as do not reach water will not undergo development, and hence a first check to the increase of the flukes exists in the fact that many eggs must perish from the absence of appropriate surroundings. Sooner or later, the young fluke loses its power of swimming, and becomes of oval shape; crawling inelegantly, by contractions of its body, over the muddy bottom of its pool or river. Thereafter it appears to seek an entrance to the body of some co-tenant of its pool, such a creature being usually found in the shape of a water-snail. Buried within the tissues of this first "host," the young fluke becomes transformed into a sac or bag, within which other young may arise by a veritable process of budding. This rising generation appears in the form of small bodies, each provided with a vibratile tail. From the body of the snail these "secondary young" soon make their escape, and whilst existing in the water are readily conveyed into the stomach of the sheep in the act of drinking. Thence these young flukes penetrate to the liver of the animal, and become transferred into the mature and flattened adult.

The unexplained necessity for such a complicated series of changes in development, and for the varied circumstances which mark the career of the young fluke, present us with conditions which operate powerfully against the undue increase of the race. An exactly analogous series of changes is to be perceived in the development of many other parasites, and amongst others in that of the various groups of tapeworms (Figs. 12 and 13), which reside within the digestive system of man and many quadrupeds, and which are in reality "compound" animals, each joint being a semi-independent unit of the compound being. But for the complexity of their development, and for the consequent limitation of their increase, these parasites would

overrun and exterminate their hosts in a short period of time. A common tapeworm begins life as a minute body, set free from its coverings and investments, and provided with a special boring apparatus, consisting of six hooks.

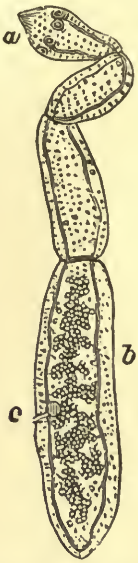

FIG. 12.—Tapeworm (*Tænia echinococcus*) of dog, in its mature condition: *a*, head, with suckers; *b*, a full-grown joint; *c*, aperture by which the eggs escape.

This little creature will perish unless it can gain access to the body of some warm-blooded quadruped, and the pig accordingly appears on the scene as the most convenient host for the reception of the little embryo. But within the body of the pig there is not the slightest possibility of the little embryo becoming a tapeworm. The pig has merely to perform the part of unconscious "nurse," and to prepare its "guest" for a yet higher stage of existence. Being swallowed by the pig, the young parasite bores its way through the tissues from the digestive system to the muscles of the animal, and there develops around its body a kind of bag or sac. In this state it represents the "cystic worm" of old writers; and occasionally it may prefer the liver, brain, or even the eye of its first host to the muscles in which it usually resides. Here, however, it can attain no further development. If the pig dies a natural death there can be no possibility of the tapeworm stage being evolved. But if, as is most likely, the pig suffers death at the butcher's hands, the little cystic worms may be bought by mankind at

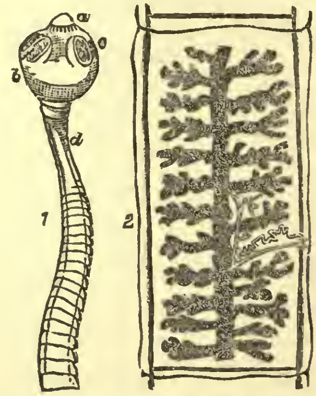

FIG. 13.—Common tapeworm (*Tænia solium*). 1. The head, magnified, showing hooks (*a*), and suckers (*b*, *c*); *d*, the neck, with immature joints. 2. A joint, largely magnified, showing the branching "ovary," in which the numerous eggs of each joint are matured.

large along with the pork in which they are contained. Such persons as partake of this comestible in an imperfectly cooked condition thereby qualify themselves for becoming the "hosts" of tapeworms; since, when a cystic worm from the muscles of the pig is introduced into the human stomach, the little bladder or sac which the worm possesses drops off, and the minute head of the worm (Fig. 13, *a*) becomes attached to the lining membrane of the digestive system. Once fixed in this position, the circle of development may be said to be completed. A process of budding sets in, and joint after joint (Fig. 13, 2) is produced, until the adult tapeworm, measuring, it may be, many feet in length, is developed; whilst each egg of this full-grown being, if surrounded by the requisite conditions, and if provided with a pig-host to begin with, will repeat the marvellous and complicated life-history of its parent.

The history of the tapeworms, like that of the flukes, therefore, exhibits a very complex series of conditions, and unless these conditions are fulfilled by

the young parasite, development is either cut short or is altogether suspended. The fact of a double host having to be provided for the due development of tapeworms is not peculiar to the production of the species inhabiting man. All of these parasites pass through an essentially similar series of developments. The cystic worms, or immature tapeworms, which cause the "measles" in the pig, become, as we have seen, and when eaten by man, the common and adult species of human tapeworm (Fig. 13). The cystic worms man obtains from underdone beef are developed within his economy into a tapeworm of another kind. The young parasites which reside in the liver of the rabbit, and which attain no higher development than that seen in the pig or ox, become when swallowed by the dog or fox the special tapeworm-tenant of these animals. The cystic worm of the mouse develops into the tapeworm of the cat; so that the dog, fox, and cat do not enjoy an immunity from enemies, but actually acquire disease from the victims they so ruthlessly pursue. The chances of destruction which beset the young parasite on its way through the world are so multifarious when compared with its chances of favorable development, that, practically, the immense number of eggs produced by these animals are of small account. Of the thousands of eggs developed, the merest fraction attain development, and the presence of a complex life-historyin parasites must be regarded as in reality forming a saving clause, as far as man is concerned, when we consider our comparative immunity from their attack.

Even more extraordinary than the phases of development which have just been detailed are those undergone by a special form of tapeworm inhabiting the dog. The egg of this latter parasite gains admittance to the body of the dog-louse, and therein becomes the cystic worm, analogous to that formed within the muscles of the pig in the case of the human tapeworm. The dog, in the process of cleaning his skin, swallows the skin-parasite with its contained but immature tapeworm; and, once introduced to the dog's digestive system, the latter form liberates itself from the louse and becomes the mature and adult tapeworm. Anything more extraordinary than this peculiar circle of development can hardly be imagined in the life-histories of animals. Nor are the conditions which have determined and which continue the development rendered clear to us by the most careful study of the subject. Why is it that the tapeworm should not attain its full development within the pig, rabbit, mouse, or dog-louse, as its first host, we do not know; nor can it be rendered plain what conditions have so sharply divided the life of these parasites into two periods of such well-marked kind.

The whole question of parasitism, however, exhibits a striking illustration of the influence of habit and of surrounding conditions on the life of the animals. No one may doubt that the habit of one animal attaching itself to another is an acquired one. The most ardent advocate of the doctrine of special creation would never dream of maintaining that parasites were created as we find them in relationship with their hosts. Even were this argument advanced as a mere matter of unsupported belief, the order and the succession of life upon the globe would present facts which would at once veto the belief. The lowest animals appeared first, and were succeeded by forms of gradually increasing complexity. Hence the parasites must have been developed before their hosts. Man appeared long after the tapeworms or their ancestors were produced; and the intricate relationship between man and his neighbor-animals and the parasites must have been acquired in a gradual fashion. Best of all, this opinion is supported by the information to be gained from a survey of parasitic life at large. We may begin such a survey by noting animals which attach themselves to other animals as mere "lodgers." Such are external parasites. Next may be traced parasites which depend for house-room upon other animals, but which do not

require board and sustenance from their hosts. Such "messmates" are presented by the little fishes which live within the bodies of large sea-anemones and other organisms, and which swim in and out at will, obtaining their food for the most part from the external world. A simple modification of habit in such animals would convert them into true parasites. Suppose that the guest found that it might readily obtain food by living on the matter its host elaborated for its own use, and suppose, further, that the animal-guest gradually accommodated itself by successive modifications to its new mode of life—we have thus the influence of habit brought into play and exercised upon the descendants of the first parasite in producing a literal race of such beings. Such a belief or theory is neither contrary to facts as we find them nor is it unsupported by direct evidence. Take, for example, the case of *Sacculina*

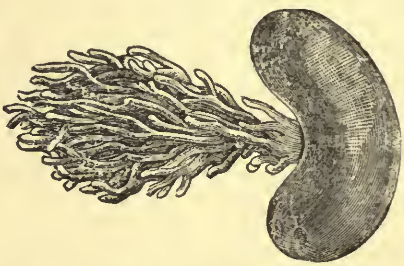

FIG. 14.—Sacculina purpurea, a crab-parasite, showing its "roots."

(Fig. 14), a well-known parasite, which attaches itself to the bodies of hermit-crabs and their allies. In shape the sacculina resembles a simple sac or bag —a kind of miniature sausage, in fact —which sends into the body of its host a number of root-like processes. These roots entwine themselves amongst the organs of the crab's body, and serve to absorb from the tissues of the host a certain amount of nourishment. If we lay open this curious organism, we find that the sac-like body contains eggs. No traces of structure are discernible; and but for occasional movements of the body, destined to inhale water and expel that fluid from its interior, one might regard the sacculina as some abnormal growth which had protruded from the body of the crab. The sacculina is a true parasite in every sense of the term. It is dependent, not merely for lodgment, but for nourishment also, upon its host; and as we shall presently note, its thorough dependence upon the crab becomes the more curious when the past history of the sacculina, as revealed by its development, is duly studied.

From each egg of the sac-like parasite thus described a little active creature (Fig. 15) is developed. Known

FIG. 15.—Young of sacculina.

to naturalists as a "nauplius," the young sacculina is seen to be utterly unlike its parent. It possesses an oval body, and is furnished with three pairs of jointed feet, which are used actively as swimming organs. By aid of the long bristles with which the feet are provided, the little sacculina swims merrily through the sea. Its body terminates behind in a kind of forked appendage of movable nature. After the lapse of a short period, changes ensue in the structure of the little body, but there appear as yet no indications of its parasitic origin, or of any tendency to imitate the fixed and attached existence of its parent. The body of the young sacculina next becomes folded upon itself, so as to inclose the young animal in a more or less complete manner; and the two front limbs become developed beyond the other pairs, and form large organs wherewith the little creature may ultimately moor itself to some fixed object. From the extremities of these altered fore limbs two elongated processes or filaments are seen to sprout, and these processes are regarded as the beginnings of the root-like organs seen in the attached, parasitic, and full-grown

sacculina. The other two pairs of feet are cast off. and in their place six pairs of short swimming feet of forked shape are developed. After this stage has been attained. the young animal seeks a crab-host; the root-like front feet attach themselves to the body of the crab and penetrate into its substance; the other feet are cast away as useless organs; and with the assumption of the sac-like body, the young sacculina becomes converted into the likeness of the parent-form.

Such is a brief sketch of the development of a true parasite, and we may now inquire what the life-history of this animal teaches us concerning its antecedents, and regarding its assumption of a parasitic life. The most reasonable view which can be taken of the development of an animal or plant is that of regarding the phases of its production as presenting us with a condensed or panoramic picture of the stages through which it had passed in the course of its origin or evolution from some pre-existing form. If we refuse to regard development in this light, the stages through which the living being passes in its progress toward maturity present themselves as a set of unmeaning and wholly inexplicable actions and conditions. Whilst, on the other hand, when we recognize that in the development of an animal we may trace its ancestry, much that is otherwise incomprehensible becomes plain and reasonable, and very discordant phases of life become harmoniously adjusted through such a consideration. And when we further discover that a large number of animals, widely differing from each other in their adult structure, exactly resemble each other in their young state, the feasible nature of the statement that such a likeness implies a common origin is readily demonstrated. On any other supposition, in short, the development of living beings presents us with phases of utterly unintelligible nature.

Now, the young sacculina is found to present a close resemblance to a large number of other animals belonging to the great class known as the *Crustacea*. To this group belong the barnacles, water-fleas, fish-lice, shrimps, crabs, lobsters, etc. Most of these animals leave the egg in the form of a "nauplius," and present the closest possible resemblance to the young sacculinæ. The young of the fixed and rooted barnacles (Fig. 16), which attach themselves

FIG. 16.—Young barnacle.

like pseudo-parasites to the sides of ships, so closely resemble young sacculinæ that it would be a difficult, if not absolutely an impossible, task to separate or distinguish the young from those of the sacculina in the earlier stages of growth. The young barnacle (Fig. 16), like the young sacculina, resembles a shrimp of peculiar kind on a roving commission, much more closely than it does the adult and attached form. And hence we discern in the common likeness of the young of these animals a proof of their common origin. At one time, therefore, we may believe that the sacculina existed as a free swimming creature, of active habits, and possessing a tolerably high degree of organization. Doubtless some less energetic member of the sacculina family secured a temporary resting-place on the body of the crab, and found such a position to be of desirable kind from the rest and protection it afforded. The feelers or feet, which were at first used for mere attachment, may have come in time to penetrate the body of the crab-host, and may thus have become transformed into organs of nourishment. By and by the sedentary life, with its

advantages in the way of cheap living and easy existence for the sacculina, would become a fixed habit. The sacculinæ, which acquired this habit, together with their descendants, would flourish and increase in numbers owing to the advantage gained by them in that "struggle for existence" in which sacculinæ and their highest animal-neighbors are forced, one and all, to take part. And as the wholly free sacculinæ became transformed into higher forms of life, or became extinct, their rooted and parasitic brethren may be regarded as having gradually degenerated. A process of physiological backsliding invariably takes place in such cases. This retrogression would be manifested in the sacculinæ by the casting off of structures which were no longer of use to a fixed and rooted being—the degeneration and disappearance of structure not required in the animal economy taking place in virtue of the well-known law of the "use and disuse" of organs. The legs would thus become gradually diminished, and would finally disappear altogether. Internal organs, and parts useful to the free-swimming animal, would become useless as the creature became more and more dependent on its host. Finally the sac-like organism would be evolved as the result of its parasitic habits; and the degeneracy which marks the slavishly dependent mind in higher life is thus viewed as also destroying the independence and as warping and distorting the character which once marked the free and active creature of lower grade. Thus we may understand, by the study of life-histories such as those of the sacculina and its comrades, how parasitism is induced, and how a change of life and habits of such sweeping character, converting an active being into a sedentary and degraded animal, becomes established through the slow but sure effects of habit, use, and wont, perpetuated through many generations.

Perhaps the most inveterate and dreaded enemy which man has to encounter in the ranks of parasites is the little *Trichina* (Fig. 17), which has, on more than one occasion, caused a fatal epidemic, on the Continent especially, through its development in excessive numbers. This little worm-like para-

FIG. 17.—Trichina imbedded in muscle, magnified.

site was first discovered in the dissecting-room of St. Bartholomew's Hospital. The circumstances of its discovery have been frequently repeated in anatomical rooms by the observation that very small hardened bodies are to be sometimes met with imbedded among the muscular tissue of the human subject. When one of these little bodies is carefully examined, it is found to consist of a little sac or bag of oval shape (Fig. 17), containing within it a little worm coiled up in a spiral fashion. These sacs attain a length of about the one-seventieth of an inch or so, and if they have existed within the muscles for a lengthened period, they will be found to be somewhat limy in structure; the presence of this mineral implying degeneration of the sac and its tenant. When the first trichinæ were examined and named by Professor Owen, their life-history and importance, as regards the human economy, were unknown and undreamt of. But the occurrence on the Continent of certain mysterious cases of illness, and the careful investigation of such cases by medical men, led to the recognition of the fact that this tiny worm, which, in its fully grown condition (Figs. 18 and 19), does not exceed a mere fraction of an inch, may nevertheless, through its development in large numbers, prove a source of fatal disease to man. In proof of this fact we may quote Dr. Cobbold's extract from the *Leipziger Zeitung* for December 8, 1863, in which it is stated that six persons were seized

with all the symptoms of trichina disease, "after eating *raw* beef mixed with chopped pork." The *Neue Hannoversche Zeitung* for December 13 of the same year chronicles the death of twenty-one persons in Hettstädt through eating the flesh of an English pig, the butcher himself perishing from the trichina disease. Eighty persons, according to the *Zeitung für Norddeutschland*, were affected in December, 1863,

FIG. 18.—Trichina (female), magnified.

in Plauen, but only one died. In 1862, of thirty-eight persons attacked in Calhe, near Magdeburg, eight died; and in Hettstädt twenty died out of a total of 135 who were attacked.

The symptoms exhibited by the patients were those of an acute fever, accompanied by distressing pains in the muscles. The discovery of the trichina's fatal powers, as might be expected, caused no little consternation, but we are not aware that the affection of our Continental neighbors for raw meat declined in consequence. If one narrative, indeed, is to be trusted, there were not wanting, it seems, those who affected an entire disbelief in the trichina and in the fatal effects it was capable of inducing. One headstrong *savant* was thus said to have fallen a victim to his scepticism. Holding in his hand a piece of sausage which he alleged had been declared to contain trichinæ, he avowed his entire disbelief in the fatal effects which were said to follow the introduction of those parasites within the human economy. He would, in fact, have no objection, for that matter, to eat the sausage. "Eat! eat!" was the cry which resounded through the hall, and in compliance with the request, the *savant* ate the sausage. Lamentable to relate, the trichinæ proved too much for even a scientific organization, and the subject of the experiment was said to have died from the trichina disease induced by his own act. Nor may the fatality of the trichina disease be regarded as a mystery in the light of the facts as to the numbers of the parasites which one "host" may contain. Dr. Cobbold affirms, and with good reason, that 20,000,000 of trichinæ may be contained in one subject. In one ounce of muscle taken from a cat which had been experimented upon as a producer of trichinæ, Leuckart estimated that 325,000 of the parasites were contained. An average-sized man, weighing ten stones, will carry about four stones of muscle; and assuming that all the voluntary muscles of the body were affected, such a person might afford lodgment to 30,000,000 of these parasites. In this instance, therefore, numbers clearly mean power, and that, too, of a fatal kind.

The history of the trichina's development again brings before us a most singular series of phases, and once more presents us with the necessity for a "double-host," as in the case of the tapeworms. If we start with the trichinæ as they exist within the muscles of the pig, we find that the parasites are contained each within the little sac or cyst already mentioned. The pig, it may be remarked, is not the only host which affords lodgment to the trichina, since dogs and cats, rats and mice, rabbits and hares, oxen, horses, sheep, guinea-pigs, and other animals, are found to be subject to their attack. It

FIG. 19.—Trichina (male), magnified.

must, however, be noted that, as found in the muscle of any animal, the trichinæ are not only perfectly harmless to that animal, but, further, exist in an undeveloped or immature condition. As seen inclosed in their little sac-like cradles (Fig. 17), the trichinæ are, in every sense of the term, "juvenile" parasites. They represent, in fact, a young and rising generation waiting for a favorable turn of Fortune's wheel to start them on the further stages of their life-history. This favorable turn arrives at the moment when the flesh containing the young and immature trichina-population is eaten by a warm-blooded animal. Suppose the "trichinaised" flesh of a pig to be eaten, without due culinary preparation, by man, the result of the preliminary processes of digestion in the stomach is the dissolution of the little cysts, and the consequent liberation of the "juvenile" population. In two days thereafter the precocious "juveniles," influenced by the change of life and situation, have become mature trichinæ, and, after the sixth day, enormous numbers of eggs are produced by these matured forms. After this stage has been attained, the parent parasites become of no further account in the history of the host, but the young form the subjects of grave concern. This new generation is found to be a restless and migratory body, and influenced by the habits of their ancestors, the young pass from the digestive organs, through the tissues of the body, to seek a lodgment in the muscles. Now comes the tug of war—for the host at least. With thousands of these microscopic pests boring their way through the tissues, there is no lack of explanation of the excessive muscular pains felt by the trichinaised patient. But relief comes in due course when the restless brood has located itself in the muscles. There each young trichina develops around itself a cyst or capsule, and returns to the primitive form in which we first beheld it. There, also, it will rest permanently, and degenerate into a speck of calcareous matter—unless, indeed, an unlooked-for contingency arises. Were cannibalism a fashionable vice amongst us, the eaters would receive from the muscles of the eaten the young population of trichinæ, just as the original subject received the juvenile brood from the pig. Within the cannibal organization, the young parasites would become fully developed, would produce young in large quantities, and would inflict upon the digester of human tissue, pains and grievances compared with which the proverbial troubles which afflict the just are as nothing.

Less to be dreaded than the trichina, but more extraordinary in its habits, is the "Guinea-worm," a well-known parasite, confined in its distribution to certain portions of Arabia, to the banks of the Ganges, and to Abyssinia and the Guinea coast. From the latter locality the organism derives its name. The Guinea-worm troubles not the internal economy of man, but has, strange to say, a striking and persistent aptitude for locating itself under the skin of the legs and feet. The interest with which the Guinea-worm is regarded by naturalists and others is derived from the fact of its curious life-history and habits, and from the supposition that this parasite represents the "fiery serpents" which so exercised the minds and tortured the bodies of the ancient Israelites. This supposition is somewhat strengthened by the knowledge that Plutarch, in his "Symposiacon," quotes a remark to the effect that "the people taken ill on the Red Sea suffered from many strange and unknown attacks," and that amongst others worms, "little snakes which came out upon them, gnawed away their legs and arms, and when touched, retracted, coiled themselves up in the muscles, and there gave rise to the most insupportable pains." Making allowance for a few exaggerations, such a description, especially in its latter portion, applies very closely to this curious enemy of man. In length, the Guinea-worm may vary from one to six feet, whilst specimens of twelve feet in length are not unknown. The body is cylindrical in shape, and attains a thickness of about one tenth of an inch.

Curiously enough, not a single male Guinea-worm has yet been met with, all the known specimens belonging to the opposite sex. The worm enters the skin as a minute organism which possesses a singular vitality, and which exists in its free condition in muddy pools, in wells, tanks, and in marshes. In all probability the young Guinea-worm gains access to the skin through the sweat-ducts. Once located within the skin, the animal grows rapidly, and in about a year attains the dimensions just given. Every traveller in the East knows the Guinea-worm by repute, and has witnessed the familiar operation performed for its extraction. Ancient works on medicine contain the descriptions of this operation, and exhibit drawings of the worm and of the appearances produced by its tenancy in the skin. The sole aims of the operator are those of extracting the parasite by gentle traction, and of avoiding the infliction of any injury to its body. This latter forms, in fact, the great *desideratum* of the operator ; since, if the body of the parasite be broken, and a portion left still within the body of its host, additional and it may be serious irritation is thereby set up. The long slender body of the worms is accordingly wound slowly and carefully around some object, and the negroes of the Guinea-coast are said to be dexterous and skilful in the performance of this somewhat delicate operation.

Perhaps one of the most remarkable points in the history of parasites is that which refers to the geographical distribution of certain of their numbers. That parasites require to be provided with certain appropriate conditions for development is a fact already noted. Indeed, we may go much farther and say that the conditions demanded for the successful developments of many of these animals are infinitely complicated, and are in many cases of singularly curious nature. But it would also seem that in their " distribution " over the surface of the globe, and in their selection of certain countries or regions as especial spheres of development, some parasites evince remarkable traits of character. One of the best known instances of this fact is afforded by a species of tapeworm, to which the somewhat uncouth—to ears unscientific, at least—name of *Bothriocephalus* has been given. This latter is a species of " broad-headed " tapeworm, differing from its common neighbors in special points. It is unquestionably the largest or longest parasite which invades the human territory, and may attain a length of over twenty-five feet ; its average breadth being about an inch or rather less. In a large " broad-head," as we may call it, upward of four thousand joints or segments may exist, and as each joint—after the first six hundred—is capable of producing eggs and embryos, this foreign neighbor is seen to be fully as productive as its commoner relations. The most interesting fact regarding the " broad-head," however, relates to its geography and to its exact range amongst the human populations of the earth. It is a tolerably well-ascertained fact, that our common tapeworms may affect inhabitants of any climate, but the " broad-headed " species affects a singularity in its distribution in that it has never been known to occur outside the European province—that is, it has never been found in any other continent save in cases where it has been conveyed to other continents by European hosts. But the " broad-head " is, moreover, found to affect certain districts or regions within this European area, so that its distribution in Europe is itself of peculiar kind. Its headquarters appear to be the cantons of Western Switzerland and the nearest French provinces. It affects Poland, Russia, and Sweden in the north and north-western parts, and it also occurs, but less typically, in Holland and Belgium. In Eastern Prussia and Pomerania the " broad-head " has occasionally appeared ; but the latter districts are probably to be regarded in the light of occasional habitats rather than of stated and permanent kind.

The reasons for the restrictions of the parasite to such a limited field are by no means clear. We are not yet suffi-

ciently acquainted with its development and life-history to make generalizations, but one significant fact remains to be noted, namely, that the "broad-head" flourishes in the regions in which the common tapeworm is an unknown or comparatively rare visitant. Now this observation is exactly paralleled by the peculiarities of the distribution of higher animals. In one country we may find what are termed "representative species" of the animals which occur in another and distant region. Thus the puma in the New World assumes the place of the lion of the Eastern hemisphere; the tapirs of the Eastern Archipelago are balanced in the opposite side of the world by the American species; and the llamas of South America represent their camel neighbors of the Old World. There thus appears in such cases to be a balancing of animal life: the one species in one region or continent assuming the functions of the nearly related but different species inhabiting another area of the world. Regarding the case of the parasites in this light, we may deduce a similar conclusion, namely, that the "broad-head" may discharge in its especial field of action the functions performed in other fields or areas by the common tapeworm. Nature, in any case, may certainly be credited with the general avoidance of any confusion of interests, and with the exclusion of rivalry from the domain and functions of like or nearly related creatures, wherever that domain may exist, and whatever these functions may be.

As a final example of a most singular and at the same time utterly harmless little intruder on the human domain, may be mentioned the minute mite known to naturalists as a species of *Demodex* (Fig. 20), and which, curiously enough, seems to take up its abode in the ducts or "follicles" of the skin at the sides of the nose. It is highly probable that this little creature is very frequently to be found in the situation just mentioned, its minute size and harmless character preventing our being made aware of its mere existence. Demodex measures a mere fraction of an inch in length, and may be said to present us with yet another instance of an organism whose selective powers in the choice of a habitation appear to be of the most singular description.

The lessons to be drawn from a consideration of the entire subject of the parasitic enemies of man bear very strongly on questions of common hygiene and sanitation. The extension of our knowledge of parasites and of their life-histories clearly points to the desirability for the exercise of great care in the choice and preparation of our common foods—especially of animal kind. Uncooked animal food in any form should be unhesitatingly rejected on common sanitary grounds—the prevailing and fashionable taste for "underdone" meat notwithstanding. The

FIG. 20.—Demodex, magnified.

Mosaic abhorrence of the pig is fully justified by an appeal to zoological knowledge regarding the parasites to which that familiar and not uninteresting quadruped plays the part of entertainer and host; but the due exercise of the culinary art should in large measure mitigate the severity of the sentence passed against pork as a common medium of parasitic infection. Unwashed vegetables, which may harbor or lodge, without developing, the embryos of parasites, are similarly to be regarded with suspicion. Indeed, it may be said that the chances of parasitic infection from this latter source are greater than those from badly cooked meat, the vegetable matter escaping even the chance of having its minute tenants destroyed. Unsavory as the subject may at first sight appear, the whole question before

us teems with an interest which should effectually appeal to every one in the light of saving knowledge. And it is not the least worthy remark which may be made regarding such a topic, that zoological science may be shown capable of extending its interests into the most intimate departments of the household, and even of encroaching on the sphere of that domestic autocrat, the cook.

WHAT I SAW IN AN ANT'S NEST.

Amongst those spectacles and incidents in human existence which remain fixed on the memory of the spectator from their sad or unwonted nature, that of a panic-stricken crowd, gathered by the report of some national disaster, stands pre-eminent. Still more terrible in its details is the history of some catastrophe which has laid a city in ruins and wrought death and desolation to thousands of the inhabitants. A deadly epidemic, or fatal plague, searing a nation with its dread, mysterious power, is a calamity appalling enough; but the spectacle of a city overthrown at one fell swoop by the earthquake shock may perhaps rank foremost amongst the untoward incidents which environ the sphere of man. A certain event, occurring during a recent holiday by the sea, tended forcibly to impress upon the mind that the great catastrophes of life are not limited to humanity's special sphere, and that in lower life panic and alarm seem to exercise no small influence, as in man's estate; whilst the incident referred to also afforded food for reflection on topics not far removed from some weighty matters in the history of man's own nature and constitution. In this latter view, it is especially hoped the observations of a brief period of leisure-time may not be without their due meed of interest.

The chance removal, from its secure site, of a large stone placed in close proximity to the sea-beach, where the bliss of idleness was being fully exemplified by a small party of holiday-makers, proved, on close examination, to be the cause of a literal revolution in lower life. Imagine a city to be totally unroofed; try to conceive of the sudden downfall of houses and buildings, and the consequent panic of the inhabitants, and you may obtain an idea of the disturbance our simple procedure effected in the peaceable, well-ordered colony of ants which had located themselves securely beneath the friendly shelter of the stone. The scene presented to view was one of the most curious and interesting which could engage the attention of an observer in any field of inquiry, and the occurrence certainly banished the idle mood of the time, and lent a zest to the subsequent hours of our holiday. Running hither and thither in wild confusion were the denizens of this underground colony; their six little legs carrying their curious globular bodies backward and forward over the disturbed area from which the stone had been removed. At first the movements of the ants were extremely erratic and purposeless. Panic and alarm appeared to be the order of the day during the few minutes which elapsed after removal of the stone. But soon the eye could discern movements of purposive kind on the part of the alarmed residents. There was "racing and chasing" in all directions; but the ants which had at first radiated from the centre of disturbance, as if on some definite quest, soon returned thereunto, and continued to advance and retire from the field of action with tolerable regularity. Not less than sixty or seventy ants appeared to be engaged in this labor of scouring the country around. The object of their repeated journeys in all directions was soon discovered. They were the self-appointed scouts, engaged in the work of reconnoitring. Such at least is a fair interpretation of the acts of the ants, and such also is the conclusion, borne out by the subsequent course of events. For, after the scouts had spent a considerable time in their rapid journeys to the environments of the nest, a new set of ants appeared upon the scene, destined to perform a highly important series of labors.

The scouts continued their journeyings, and gave one the idea of a set of

fussy individuals who were superintending, or even bullying, their new neighbors, who appeared from amongst the ruins and *débris* of the ant city, carrying in their mouths certain oval bodies of a dirty-white color, and measuring each about one third of an inch in length. Each of these bodies closely resembled a grain of corn in shape, size, and appearance. The spectacle of these small insects carrying off these bodies in their powerful jaws impressed one forcibly with the idea that, relatively to its size, an ant is an herculean insect.

Occasionally there might be seen certain rather ludicrous incidents connected with the removal of the objects in question. One ant might be witnessed in the endeavor to hoist the oval body it was carrying in its mouth over some obstacle lying in the path, and the staggering gait of the insect seemed very accurately to mimic the similar disposition of a human porter struggling under a burdensome load. Another ant, carrying the oval body before it, would arrive at a steep incline formed of loose sand, and presenting a treacherous surface even to the light feet of the insect. The efforts of the ant to carry the body upward being found to be fruitless, the insect might be seen to whirl about with great rapidity of action, and ascend the hill backward, pulling the body after it, instead of pushing it as before.

Another instance might be witnessed in which an ant which had literally come to grief with its burden would be assisted by a kindly neighbor; but it was no uncommon sight to behold in the excessive eagerness of the insects an actual means of defeating the object they had in view, since two ants would in some cases seize the same burden, and then came the tug of war. One pulled one way whilst the other tugged in the opposite direction; and the observer could almost have supposed that the burden itself might have been parted in twain by the treatment to which it was subjected —the incident affording a new application of the remark that a surfeit of zeal is destructive of the best intentions. The nature of the bodies which the ants seemed so excessively anxious to preserve from injury was readily determined. The oval bodies, resembling grains of corn, were the *pupæ* or *chrysalides* of the ants—the sleeping babies and young hopefuls, on whom the hopes of the colony were, and, I may say, are, founded. It is noteworthy, however, that upon some mistaken notions regarding the nature of these bodies many of the ideas concerning the frugal care of these insects were founded. Solomon's advice that the sluggard should "go to the ant," with the view of considering her ways and of gaining wisdom as a result of the study, was in days of old thought to be approved by the observation that the ants husbanded their stores of food in the shape of the grains of corn they had gained from the autumnal store. There can be little doubt that some species of ants do store food; but their praiseworthy actions in this direction have been greatly exaggerated, and there appears, indeed, to be some danger of idle persons being prepared with the retort to the wise man, that the ant is by no means the model creature he thought her to be. If, however, the supposed corn-grains turn out to be the rising generation of ants in their chrysalis-state, it may be said that what the ants may have lost in the way of fame in this direction has been amply compensated for by the discovery of more wonderful traits of character than Solomon could possibly have dreamt of.

The work of removing the developing population thus appeared in our ant's nest to absorb the entire energies of the alarmed denizens. Pupa after pupa was carried out from amongst the *débris* and taken for a considerable distance—certainly fifteen inches—to a place of security, beneath a small sloping stone of flat shape, which roofed over a hollow in the ground. So far as I could observe, the scouts must have discovered this place of refuge, and have communicated the intelligence to their neighbors. The regularity with which the slumbering innocents were conveyed to the same spot would appear to point to concerted work and to a definite idea, if one may so term it, having animated the laborers. I was

careful to ascertain at an early stage of the proceedings that the place of refuge had no communications with the nest. It was, in point of fact, an entirely new habitation, and, as far as human judgment might venture upon an opinion, the new residence appeared to give promise of being a safe and convenient domicile. Now and then an ant would emerge from the ruins of the nest carrying a younger hopeful in the larva or caterpillar stage. This latter was a little white grub, which corresponds in its development to the grub or caterpillar of the butterfly or fly ; the ants thus exemplifying insects which undergo a complete "metamorphosis." It was rather a difficult matter to ascertain clearly if the ants were actually excavating the chrysalides from amongst the *dêbris*. Bearing in mind what Sir John Lubbock has told us concerning the apparent inability of ants to discover the whereabouts of companions buried under earth, I rather lean to the belief that my ants simply conveyed to a place of safety those chrysalides which were at hand and readily obtainable. The latter fact I could not ascertain, since I feared to disturb the ants at their interesting labors ; but a simple experiment served to show the feasibility of the idea that the crysalides were probably within easy reach of the ants.

Taking possession of one chrysalis which was being conveyed to the new domicile, I buried it about half an inch deep in the sand, directly in the track over which the ants were journeying to their new residence, and a second chrysalis I placed at a little distance from this track, but in a spot over which numerous ants were running apparently without any definite aim. The second pupa-ant was not buried in any sense, and was covered merely with a sprinkling of sand. The result in both cases was negative. No attempt was made to disinter the chrysalis from the beaten track, although numberless ants walked directly over it ; and I extricated the chrysalis five hours after its interment, and when the busy scene of the morning had been replaced by a dull prospect, over which only a single ant now and then hurried in a rapid fashion. The other chrysalis was also unnoticed, despite its proximity to the surface of the sand. Whether or not ants want a sense of smell or other means of guiding them to the whereabouts of their neighbors or children, is a subject difficult of determination either toward a positive or negative result. And I am the more inclined to wonder at the incapacity of the insects to discover their buried companions, since they appear to be perfectly capable of detecting them at a considerable distance above ground. When a chrysalis was placed in a spot remote from the nest, and an ant placed within a foot or so of the chrysalis, the insect would occasionally seem to be attracted to the neighborhood of the object. I frequently observed that if an ant happened to crawl within two or three inches of the chrysalis as it lay on the ground, it appeared to become conscious of the object, although at the same time it seemed ignorant of its precise locality. In such a case the insect would proceed hither and thither in an erratic fashion, but would continue to hover or rotate around the chrysalis until it seized the object and bore it off in triumph in its jaws. Relatively to the size of the ant, we must consider this latter incident by no means a slight tribute to its acuteness.

The busy scene resulting from the disturbance of the nest proceeded actively during at least two hours. The nest appeared to be by no means a large one. At the end of two hours, however, the ants were still rushing hither and thither, bent on errands unknown to their observers, although the work of conveying the chrysalides had at the lapse of the period just mentioned entirely ceased. Five and a half hours after the nest had been alarmed, not an ant was visible over the disturbed area, and our next task was that of investigating the manner in which the insects had dispersed themselves and their belongings in their new habitation by carefully removing the flat sloping stone already mentioned as that beneath which the main stream of the ants had disappeared. Not an insect was to be seen

after this operation was performed, and it was only after the removal of several small stones which lay below the flat stone that the colony in its new sphere was brought into view. Our investigation once again excited the restless beings. Then ensued, for the second time, the seizure of the chrysalides, which, however, were to be seen packed together in a secure position and already partly covered with particles of earth and sand. To have reached the position in which we found them, the insects must have descended at least three inches after entering below the stone, and the labor of the continual ascent in search of fresh chrysalides must therefore have been of no light kind. We saw enough to convince us that the ants had already settled down in a new organization, which, with an undisturbed history, might repeat the peaceful state of their former life ; and we also had the thought presented, that in the exercise of their duties under the pressure of an unwonted exigency, the insects behaved and acted with no small degree of intelligence, and apparently in harmonious concert to the desired end.

But the thoughts suggested by the brief observation of the disturbed ant's nest hardly end thus. We may very naturally proceed to inquire into the regular organization and constitution of the ant colony, and also, as far as fact and theory may together lead, into the analogies—if analogies there be—which exist between the social instincts of ants and the ways of the higher animals, man included.

The common ants and their neighbors belong to the order of insects known as the *Hymenoptera*, a group represented by other insects of "social" habits, such as bees, wasps, and hornets. The termites, or white ants of the tropics, are the only "ants" foreign to this order of insects, the white ants being near relations of the dragon-flies, May-flies, etc. The family history of the latter, as told by Mr. Bates, may serve to introduce us agreeably to ant society at large. The nests of the termites may attain a height of five feet, and present the appearance of conical hillocks, formed of earth particles "worked," says Mr. Bates, "with a material as hard as stone." In the neighborhood of the nests, narrow covered galleries or underground ways are everywhere to be seen, these latter being the passages along which the materials used for building the nests are conveyed. The termites are small soft-bodied animals of a pale color, but resemble the common or true ants in that they live in colonies, composed, like those of bees, of three chief grades of individuals. These grades are known as males, females, and blind "neuters," the latter forming at once the largest bulk of the population, and including in their numbers the true "working classes" of this curious community. In the common ants, the "neuters" are regarded as being undeveloped female insects. These neuters exhibit in the termites a further division into ordinary "workers" (Fig. 21, 4), which perform the multifarious duties connect-

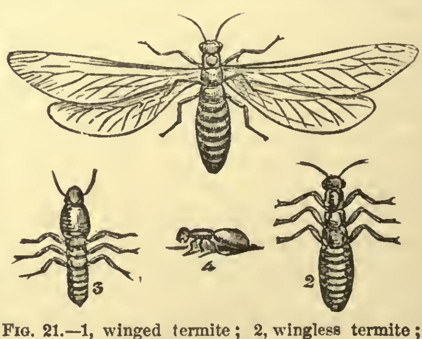

FIG. 21.—1, winged termite ; 2, wingless termite ; 3, soldier ; 4, worker.

ed with the ordinary life of the colony, and "soldiers" (3), which perfectly exemplify the laws of military organization in higher life, in that they have no part in the common labor, but devote themselves entirely to the defence of the colony and to the

"Pride, pomp, and circumstance of glorious war."

The workers appear to perform a never-ending round of duties. They build the nests, make the roads, attend to the wants of the young, train up the latter in the ways of ant existence, wait on

the sovereigns of the nest, and like diplomatic courtiers, duly arrange for the royal marriages of the future. As Mr. Bates remarks, "The wonderful part in the history of the termites is, that not only is there a rigid division of labor, but nature has given to each class a structure of body adapting it to the kind of labor it has to perform. The males and females form a class apart; they do no kind of work, but in the course of growth acquire wings to enable them to issue forth and disseminate their kind. The workers and soldiers are wingless, and differ solely in the shape and armature of the head. This member in the laborers is smooth and rounded, the mouth being adapted for the working of the materials in building the hive. In the soldier the head is of very large size, and is provided in almost every kind with special organs of offence and defence in the form of horny processes resembling pikes, tridents, and so forth. . . . The course of human events in our day seems, unhappily, to make it more than ever necessary for the citizens of civilized and industrious communities to set apart a numerous armed class for the protection of the rest; in this, nations only do what nature has of old done for the termites. The soldier termes, however, has not only the fighting instinct and function; he is constructed as a soldier, and carries his weapons not in his hand but growing out of his body." When a colony of termites is disturbed, the ordinary citizens disappear and the military are called out. The soldiers mounted the breach, says Mr. Bates, "to cover the retreat of the workers," when a hole was made in the archway of one of their covered roads, and with military precision the rear-men fall into the vacant places in the front ranks as the latter are emptied by the misfortune of war.

In a termite colony there is but one king and queen, the royal couple being the true parents of the colony. The state-apartments are situated in the centre of the hive, and are strictly guarded by workers. Both king and queen are wingless, and are of larger size than their subjects. The queen engages in a continual round of maternal duties, the eggs deposited by the sovereign-mother being at once seized by the workers and conveyed to special or "nursery cells," where the young are duly tended and brought up. Once a year, at the beginning of the rainy season, winged termites appear in the hive as developments of certain of the eggs laid by the queen-termite. These latter are winged males and females (Fig. 21, 1), the two sexes being present in equal numbers. Some of these, after shedding their wings, become the founders—kings and queens—of new communities, the privilege of sex being thus associated with the important and self-denying work of perpetuating the species or race in time. Sooner or later—a termite family takes about a year to grow—a veritable exodus of the young winged termites takes place; and just before this emigration movement occurs, a hive may be seen to be stocked with "termites" of all castes and in all stages of development. The workers never exhibit a change of form during their growth; the soldiers begin to differ from the workers in the possession of larger heads and jaws; whilst the young which are destined to become the winged males and females are distinguished by the early possession of the germs of wings which become larger as the skin is successively moulted. Amongst the bees, blind Huber supposed that an ordinary or neuter egg develops into a queen bee if the larva is fed upon a special kind of food—"royal food," as it is called. Although some entomological authorities differ from Huber with regard to the exact means by which the queen bee is reared and specialized from other larvæ, yet the opinion thus expressed possesses a large amount of probability. Whatever may be the exact method or causes through or by which the queen bee is developed, Mr. Bates strongly asserts that the differences between the soldiers and worker termites are distinctly marked from the egg. This latter observer maintains that the difference is not due to variations in food or treat-

ment during their early existence, but is fixed and apparent from the beginning of development. This fact is worthy of note, for it argues in favor of the view that if, as is most likely, the differences between the grades of termites may have originally been produced by natural selection or other causes, these differences have now become part and parcel of the constitution of these insects, and are propagated by the ordinary law of heredity. Thus acquired conditions have become in time the natural "way of life" of these animals.

Mr. Bates has also placed on record the noteworthy fact that a species of termites exists in which the members of the soldier class did not differ at all from the workers "except in the fighting instinct." This observation, if it may be used at all in elucidation of the various grades of society amongst these insects—at least the present state of our knowledge would seem to lead to such a conclusion as being much more feasible than the theory of special or sudden creation of the peculiarities of the race. It is admitted that the termites are in many respects inferior in structure to the bees and wasps, whilst the white ants themselves are the superiors of their own order—that of the *Neuroptera.* That the termites preceded the bees and their neighbors, the common ants, in the order of development of social instincts, is a conclusion supported by the fact that the *Neuroptera* form the first group of insects which are preserved to us in the "records of the rocks." Fossil *Neuroptera* occur in the Devonian rocks of North America; the first traces of in-

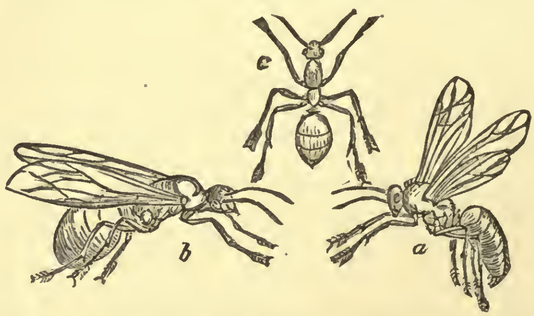

FIG. 22.—Red, or horse-ant (*Formica rufa*): *a*, male; *b*, female, winged; *c*, worker.

origin of the curious family life of these insects, points not to sudden creation, but to gradual acquirement and modification as having been the method of development of the specialized classes and castes in termite society. Firstly, we may thus regard the beginnings of the further development of a colony to appear in a nest in which workers and soldiers are alike, as stated by Mr. Bates. Then, through the practice of the fighting instinct, we may conceive that natural selection would be competent to adapt the soldiers more perfectly for their duties militant, by developing the head and jaws as offensive weapons. Possibly, were our knowledge of the termites at all complete, we should meet with all stages in the development and specialization of the sects allied to the bees and wasps being geologically more recent, and appearing in the oolitic strata. The occurrence of high social instincts in an ancient group of insects renders the repetition of these instincts in a later and higher group the less remarkable. The observation, however, does not of necessity carry with it any actual or implied connection between the termites and their higher neighbors, although, indeed, the likeness between the social life of the two orders of insects might warrant such a supposition.

The common ants (Fig. 22), the study of which in their native haunts is a matter of no great difficulty, and one which will fully reward the seeking mind, like the termites, possess three grades of individuals. In a single ant'

nest more than one female may be found, the ants differing from the bees in this respect; and in the nests of some species of ants there are apparently "soldiers" resembling the military termites in the possession of large heads and well-developed jaws. Very amazing differences are to be perceived amongst the various species of ants. Differences in size are of common occurrence, but naturalists have actually succeeded in classifying ants in a general way, by differences in manner and disposition. We know, for example, that the horse-ant (*Formica rufa*, Fig. 22) has little *individual* intelligence, but is extremely socialistic, and moves and acts *en masse* with precision and tact. Another species (*F. fusca*) is timid and retiring. *F. pratensis* is a revengeful creature, since it "worries"

Fig. 23.—Apple aphis (*Eriosoma mali*): *a*, wingless insect, magnified; *b*, wingless insect in excrescence of the tree, magnified.

its fallen foes; *F. cinerea* is bold and audacious; others are termed "thieves" and "cowards;" some are phlegmatic; and to complete the list of failings and traits which are human enough in character, one species is said to present an invariable greediness as its prevailing characteristic. The common ants resemble the termites in the general details of their life. We see in an ant's nest the same restless activity of the workers, the same earnest attention paid to the young and pupæ, the same instinct in shielding the young from danger, and much the same general routine of development. Certain rather special, and it may be said extraordinary, habits of ants may, however, demand notice before we attempt a brief survey of their instincts at large. Few readers are unacquainted with the *Aphides*, or plant-lice, those little wingless insects which infest our plants and herbs in myriads in summer. It is a fact now well known to naturalists, and first placed on record by Huber, that between the ants and plant-lice, relations of a very friendly and, as far as the ants are concerned, advantageous character have become established. Ants have been observed to stroke the tips of the bodies of the plant-lice with their antennæ, this act causing the plant-lice to exude drops of a clear sweet fluid, of which the ants are extremely enamoured. The ants would thus appear to habitually "milk" their insect-neighbors, and, as far as observation goes, some ants seem not merely to keep the plant-lice in their nests so as to form a veritable dairy-establishment, but also to make provision in the future by securing the eggs of the aphides, and bringing up the young as we rear calves.

That the relation between the ants and plant-lice are of very stable kind is proved by the interesting remarks of Mr. Darwin, who "removed all the ants from a group of about a dozen aphides on a dock-plant, and prevented their attendance during several hours." Careful watching showed that the plant-lice after this interval did not excrete the sweet fluid. Mr. Darwin then stroked the plant-lice with a hair, endeavoring thus to imitate the action of the ant's feelers, but not a single plant-louse seemed disposed to emit the secretion. Thereafter a single ant was admitted to their company, the insect, in Mr. Darwin's words, appearing, "by its eager way of running about, to be well aware what a rich flock it had discovered." The ant first stroked one aphis and then another, each insect excreting a drop of the sweet juice "as soon as it felt the antennæ;" and "even the quite young aphides behaved in this manner, showing that the action was instinctive, and not the result of experience." If, as Mr. Darwin remarks, it is a convenience for the aphides to have the sweet secretion removed, and that "they do not excrete

solely for the food of the ants," the observation does not in any degree lessen the curious nature of the relationship which has become established between the ants and their neighbors, or the interesting features in ant life which have inaugurated and perpetuated the habit.

Not less remarkable are the "slave-making" instincts of certain species of ants. It may be safely maintained that the slave-making habit forms a subject of more than ordinary interest not merely to naturalists but to metaphysicians given to speculate on the origin and acquirement of the practices of human existence. Pierre Huber, son of the famous entomologist, was the first to describe the slave-making instincts in a species (*Polyergus rufescens*) noted for its predaceous instincts, and subsequent observations have shown that other species participate in these habits. *Polyergus* is thoroughly dependent on slaves. Without these bondsmen it is difficult to see how the ants could exist. Huber tells us that the workers of this species perform no work save that of capturing slaves. Use and wont, and the habit of depending entirely on their servitors, have produced such changes in the structure of the ants that they are unable to help themselves. The jaws of these ants are not adapted for work; they are carried by their slaves from an old nest to a new one; and, more extraordinary still, they require to be fed by their slaves, even with plenty of food close at hand. Out of thirty of these ants placed by Huber in a box, with some of their larvæ and pupæ, and a store of honey, fifteen died in less than two days of hunger and of sheer inability to help themselves. When, however, one of their slaves was introduced, the willing servitor "established order, formed a chamber in the earth, gathered together the larvæ, extricated several young ants that were ready to quit the condition of pupæ, and preserved the life of the remaining Amazons." It must be noted that there are very varying degrees in the dependence of the ant-masters on their slaves. In the recognition of this graduated scale of relationship and dependence, indeed, will be found the clue to the acquirement of this instinct. The horse-ant (*Formica rufa*) will carry off the larvæ and pupæ of other ants *for food*, and it sometimes happens that some of these captives, spared by their cannibal neighbors, will grow up in the nest of their captor. A well-known ant, the *Formica sanguinea*, found in the South of England, is, however, a true slave-making species, but exhibits no such utter dependence on its servitors as does *Polyergus*. The slave-making habit is not only typically developed in the *Sanguineas*, but the bearing of the captives to their masters indicates a degree of relationship and organization such as could hardly be conceived to exist outside human experience. The *Sanguineas* make periodical excursions, and, like a powerful predatory clan, carry off the pupæ or chrysalides of a neighboring species, *F. fusca*. Thus the children of the latter race are born within the nest of their captors in an enslaved condition. As slaves "born and bred," so to speak, they fall at once into the routine of their duties, assist their masters in the work of the nest, and tend and nurse the young of the family. The slaves, curiously enough in this instance, are black in color, whilst the masters are twice the size of the servitors, and are red in color, and that the slaves are true importations is proved by the fact that males and females of the slave species are never developed within the nest of the masters, but only within those of their own colonies. The slaves in this instance rarely leave the nest, the masters foraging for food, and employing their captives in household work, as it were; whilst, when the work of emigration occurs, the masters carry the slaves in their mouths like household goods and chattels, instead of being carried by them, as in the case of *Polyergus*.

Mr. Darwin gives an interesting account of the different attitudes exhibited by the *Sanguineas* toward species of ants other than the black race from which their slaves are usually drawn. A few pupæ of the yellow ant (*F. flava*),

a courageous and pugnacious little species, were placed within the reach of the slave-making *Sanguineas*. A like chance presented with the pupæ of their slave race was eagerly seized, and the chrysalides carried off. The pupæ of the yellow ants, however, were not merely left untouched, but the slave-makers exhibited every symptom of terror and alarm at the sight of the chrysalides of their yellow neighbors. Such an instance demonstrates the existence not merely of perception but also of the memory of past experience, probably of not over agreeable kind, of encounters with the yellow ants. When, on the contrary, a nest of the slaves is attacked, the *Sanguineas* are both bold and wary. Mr. Darwin traced a long file of *Sanguineas* for forty yards backward to a clump of heath, whence he perceived the last of the invaders marching homeward with a slave pupa in its mouth. Two or three individuals of the attacked and desolate nest were rushing about in wild despair, and "one," adds Mr. Darwin, "was perched motionless, with its own pupa in its mouth, on the top of a spray of heath, an image of despair over its ravaged home." The picture thus drawn is not the less eloquent because its subject is drawn from lower existence; although the pains and sorrows of ant life may not legitimately be judged by the standard of human woe.

The explanation of the slave-making instinct in ants begins with the recognition of the fact that many ants, not slave-makers, store up pupæ of other species for food. If we suppose that some of the pupæ, originally acquired through a cannibal-like instinct, came to maturity within the nest of their captors, and in virtue of their own inherited instincts engaged in the work of the hive, we may conceive of a rational beginning of the slave-making instinct. If, further, the captors learned to appreciate the labors of their captives, as lightening their own work, the habit of collecting pupæ as slaves might succeed and supersede that of collecting them for food. In any case, we should require to postulate on the part of the slave-makers a degree of instinct altogether unusual in insects, or, indeed, in higher animals; but that such instinct is developed in ants other than slave-makers admits of no dispute. The strengthening, through repetition, of a habit useful to the species may thus be credited with the beginning of the practice of slavery amongst ants; whilst special circumstances—such as the number of the slaves as compared with the number of masters—would tend to develop a greater or less degree of dependence of the captors or their servitors.

Huber, for instance, informs us that the *Fusca*-slaves of the *Sanguineas* of Switzerland work with their masters in building the nest; they close and open the doors of the hive; but their chief office appears to be that of hunting for plant-lice. In England, on the contrary, the slaves are strictly household servants, rarely venturing out of doors. Such differences depend most probably on the fact that a greater number of slaves occur in Swiss than in English nests, and they may therefore be employed in a wider range of duties on the Continent than at home. A fewer number of slaves, a greater aptitude on the part of the slaves for their duties, the inability of the masters to perform the duties of the slaves—each or all of these causes combined would serve to increase the value of the servitors, and at the same time to reduce the independence of the masters.

This increase of the value of the slaves as active factors in the ant community might at length proceed to such extremes as we see exemplified in the *Polyergus*, already referred to—a race which has become literally unable to feed itself, and to discharge the simplest duties of ant existence, and whose actual life is entirely spent in marauding expeditions on the nests of its neighbors.

The subject of the general intelligence of ants, and of their ability to adapt themselves to awkward and unusual circumstances, may be briefly touched upon by way of conclusion.

Between the reason and intelligence

of higher animals and the "instinct" of ants there is unquestionably a great gulf fixed. I make this statement unhesitatingly, notwithstanding that I should no more willingly attempt to define "instinct" than to give an exact definition of "insanity." In the latter case one may make the definition so limited as practically to exclude all save one class of cases, or so wide as to include even the judge on the bench. In the case of instinct, the rigid definition of one authority might cause us to regard it as the exclusive property of lower forms and as having no relationship whatever with the mental powers of higher beings; or, on the other hand, as being but a modified form of, or in some respects identical with, these very powers. We know too little respecting the so-called "automatic" powers and ways, even of higher animals, to dogmatize regarding the acts of lower animals, but we may safely assume that one apparent ground of distinction between instinct and reason may be found in the common incompetence of instinct to move out of the beaten track of existence, and in the adaptation of reason, through the teachings of experience, to new and unwonted circumstances. Let Dr. Carpenter speak as an authority on such a subject. "The whole nervous system of invertebrated animals, then, may be regarded as ministering entirely to *automatic* action; and its highest development, as in the class of insects, is coincident with the highest manifestations of the 'instinctive' powers, which, when carefully examined, are found to consist entirely in movements of the excito-motor and sensori-motor kinds. (The terms '*excito-motor*' and '*sensori-motor*' are applied to nervous actions resulting in movements of varying kinds, and produced by impressions made on nervous centres, but without any necessary emotion, reason, or consciousness.) When we attentively consider the habits of these animals, we find that their actions, though evidently adapted to the attainment of certain ends, are very far from evincing a *designed* adaptation on the part of the beings that perform them. . . . For, in the first place, these actions are invariably performed in the same manner by all the individuals of a species, when the conditions are the same; and thus are obviously to be attributed rather to a uniform impulse than to a free choice, the most remarkable example of this being furnished by the economy of bees, wasps, and other 'social' insects, in which every individual of the community performs its appropriated part with the exactitude and method of a perfect machine. The very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human Reasoner."

Appealing to the most recent observations on ants, we may find evidence of the truth of Dr. Carpenter's statements, whilst at the same time we may also detect instances of the development of higher powers which are hardly to be classed as "automatic," and which, in certain species (as in the *Ecitons*, charmingly described by Mr. Belt in "The Naturalist in Nicaragua"), may be said to be elevated above the common instincts of the race. Dr. Henry Maudsley has also well summed up the relationship of the acts of these insects to the acts of higher forms, and to new adaptations when he says: "I do not say that the ant and the bee are entirely destitute of any power of adaptation to new experiences in their lives—that they are, in fact, purely organized machines, acting always with unvarying regularity; it would appear, indeed, from close observation, that these creatures do sometimes discover in their actions traces of a sensibility to strange experiences, and of corresponding adaptations of movements. We cannot, moreover, conceive how the remarkable instincts which they manifest can have been acquired originally, except by virtue of some such power. But the power in them now is evident-

ly of a rudimentary kind, and must remain so while they have not those higher nerve-centres in which the sensations are combined into ideas, and perceptions of the relations of things are acquired. Granting, however, that the bee or ant has these traces of adaptive action, it must be allowed that they are truly rudiments of functions, which in the supreme nerve-centres we designate as reason and volition. Such a confession might be a trouble to a metaphysical physiologist, who would thereupon find it necessary to place a metaphysical entity behind the so-called instincts of the bee, but can be no trouble to the inductive physiologist —he simply recognizes an illustration of a physiological diffusion of properties, and of the physical conditions of primitive volition, and traces in the evolution of mind and its organs, as in the evolution of other functions and their organs, a progressive specialization and increasing complexity."

The recently published experiments of Sir John Lubbock show that ants under certain circumstances are both stupid and devoid of any intelligent comprehension in the way of surmounting difficulties; but this distinguished observer has also shown that as regards communication between ants, and in the regulation of the ordinary circumstances of their lives, these insects evince a high degree of intelligence, and exhibit instincts of a very highly developed kind. Still, making every allowance for the development of extraordinary mental power in some species of ants, there can be little doubt of the purely automatic beginnings and nature of most, if not all, of the acts of ordinary ant existence. The young ant, wasp, or bee, will begin its labors and discharge them as perfectly at the beginning of its existence as a perfect insect, as at the close of life. Here there is no experience, no tuition, no consciousness, no reason, and no powers save such as have been transferred to the insect as a mere matter of heredity and derivation from its ancestors, who lived by an unconscious rule of thumb, so to speak. It is very hard at first to convince one's self, when watching an ant's nest, that intelligence and consciousness play little or no part in the apparently intelligent operation of these insects. But to assume the contrary would be to maintain that the insect stands on an equal footing to man himself, and for such a supposition there is neither lawful ground nor sympathy. The marvellous instinct of lower life stands on a platform of its own, has its own phases of development, and probably its own unconscious way of progress. The higher reason and intellect of humanity similarly possesses its own peculiar standard, rate, and method of culture. A man may seek and find in the ways of lower existence not merely a lesson in the ordering of his existence, but some comfort, also, in the thought that the progress of lower nature is not unknown in the domain of human hopes and aspirations.

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Beacon Lights of Science

HEREDITARY TRAITS

AND OTHER ESSAYS

By RICHARD A. PROCTOR

I.

HEREDITARY TRAITS.

In Montaigne's well known essay on the "Resemblance of Children to their Fathers," the philosopher of Périgord remarks that "there is a certain sort of crafty humility that springs from presumption; as this, for example, that we confess our ignorance in many things, and are so courteous as to acknowledge that there are in works of nature some qualities and conditions that are imperceptible to us, and of which our understanding cannot discern the means and causes; by which honest declaration we hope to obtain that people shall also believe us of those that we say we do understand." "We need not trouble ourselves," he goes on, "to seek out miracles and strange difficulties; methinks there are such incomprehensible wonders amongst the things that we ordinarily see as surpass all difficulties of miracles." He applies these remarks to inherited peculiarities of feature, figure, character, constitution, habits, and so forth. And certainly few of the phenomena of nature are more wonderful than these, in the sense of being less obviously referable to any cause which seems competent to produce them. Many of those natural phenomena which are regarded a most striking are in this respect nc to be compared with the known phenomena of heredity. The motions of the planets can all be referred to regular laws; chemical changes are systematic, and their sequence at least is understood; the phenomena of heat, light, and electricity are gradually finding interpretation. It is true that all these phenomena become in a sense as miracles when we endeavor to ascertain their real cause. In their case we can ascertain the "how," but in no sense the "why." Gravity is a mystery of mysteries to the astronomer, and has almost compelled us to believe in that "action at a distance" which Newton asserted to be unimaginable by anyone with a competent power of reasoning about things philosophical. The ultimate cause of chemical changes is as great a mystery now as it was when the four elements were believed in. And the nature of

the ether itself in which the undulations of heat, light and electricity are transmitted is utterly mysterious even to those students of science who have been most successful in determining the laws according to which those undulations proceed. But the phenomena themselves, being at once referable (in our own time at least) to law, have no longer the mysterious and in a sense miraculous character recognized in them before the laws of motion, of chemical affinity, of light and heat and electricity had been ascertained. It is quite otherwise with the phenomena of heredity. We know nothing even of the proximate cause of any single phenomenon; far less of that ultimate cause in which all these phenomena had their origin. The inheritance of a trait of bodily figure, character, or manner is a mystery as great as that other and cognate mystery, the appearance of some seemingly sudden variation in a race which has for many generations presented an apparently unvarying succession of attributes, bodily, physical or mental.

It need hardly be said that this would not be the place for the discussion of the problems of heredity and variation, even if in the present position of science we could hope for any profitable result from the investigation of either subject. But some of the curious facts which have been noted by various students of heredity will, I think, be found interesting; and though not suggesting in the remotest degree any solution of the real difficulties of the subject, they may afford some indication of the laws according to which parental traits are inherited, or seemingly sudden variations introduced.

The commonest, and therefore the least interesting, though perhaps the most instructive of the phenomena of heredity, are those affecting the features and the outward configuration of the body. These have been recognized in all ages and among all nations. A portion of the Jewish system of legislature was based on a recognition of the law that children inherit the bodily qualities of the parents. The Greeks noted the same fact. Among the Spartans, indeed, a system of selection from among newborn children prevailed, which, though probably intended only to eliminate the weaker individuals, corresponded closely to what would be done by a nation having full belief in the efficacy of both natural and artificial selection, and not troubled with any strong scruples as to the method of applying their doctrines on such matters. Among the Romans we find certain families described by their physical characteristics, as the *Nasones* or Big-nosed, the *Labeones* or Thick-lipped, the *Capitones* or Big-headed, the *Buccones* or Swollen-cheeked. In more recent times similar traits have been recognized in various families. The Austrian lip and Bourbon nose are well known instances.*

Peculiarities of structure have a double interest, as illustrating both variation and persistence. We usually find them introduced without any apparent cause into a family, and afterwards they remain as hereditary traits, first inherited regularly, then intermittently, and eventually, in most cases, dying out or becoming so exceptional that their occurrence is not regarded as an hereditary peculiarity. Montaigne mentions that in the family of Lepidus, at Rome, there were three, not successively but by intervals, that were born with the same eye covered with a cartilage. At Thebes there was a family almost every member of which had the crown of the head pointed like a lance-head; all whose heads were not so formed being regarded as illegitimate. A better authenticated case is that of the Lambert family. The peculiarity affecting this family appeared first in the person of Edward Lambert, whose whole body, except the face, the palms of the hands, and the soles of the feet,

* It is said by Ribot that of all the features the nose is the one which heredity preserves best.

was covered with a sort of shell consisting of horny excrescences. He was the father of six children, all of whom, so soon as they had reached the age of six weeks, presented the same peculiarity. Only one of them lived. He married, and transmitted the peculiarity to all his sons. For five generations all the male members of the Lambert family were distinguished by the horny excrescences which had adorned the body of Edward Lambert.

A remarkable instance of the transmission of anomalous characteristics is found in the case of Andrian Jeftichjew, who, three or four years ago, was exhibited with his son Fedor Jeftichjew in Berlin and Paris. They were called in Paris *les hommes-chiens*, or dog-men, the father's face being so covered with hair as to present a striking resemblance to the face of a Skye terrier. Andrian was thus described: "He is about fifty-five years of age, and is said to have been the son of a Russian soldier. In order to escape the derision and the unkind usage of his fellow-villagers, Andrian in early life fled to the woods, where for some time he lived in a cave.

"During this period of seclusion he was much given to drunkenness. His mental condition does not seem to have suffered, however, and he is on the whole of a kindly and affectionate disposition. It may be of interest to state that he is an orthodox member of the Russo-Greek Church, and that, degraded as he is intellectually, he has very definite notions about heaven and the hereafter. He hopes to introduce his frightful countenance into the court of heaven; and he devotes all the money he makes, over and above his outlay for creature comforts, to purchasing the prayers of a devout community of monks in his native village, Kostroma, after his mortal career is ended. He is of medium stature, but very strongly built. His excessive capillary development is not true hair, but simply an abnormal growth of the *down* or fine hairs which usually cover nearly the entire surface of the human body Strictly speaking, he has neither head-hair, beard, moustache, eyebrows, nor eyelashes, their place being taken by this singular growth of long silky down. In color this is of a dirty yellow; it is about three inches in length all over the face, and feels like the hair of a Newfoundland dog. The very eyelids are covered with this long hair, while flowing locks come out of his nostrils and ears. On his body are isolated patches, strewed, but not thickly, with hairs one and a-half to two inches long." Dr. Bertillon, of Paris, compared a hair from Andrian's chin with a very fine hair from a man's beard, and found that the latter was three times as thick as the former; and a hair from Andrian's head is only one-half as thick as an average human hair. Professor Virchow, of Berlin, made careful inquiry into the family history of Andrian Jeftichjew. So far as could be learned, Andrian was the first in whom this wonderful hirsuteness had been noticed. Neither his reputed father nor his mother presented any peculiarity of the kind, and a brother and sister of his, who are still living, are in no way remarkable for capillary development. The son Fedor, who was exhibited in company with Andrian, was illegitimate, and about three years of age. Andrian's legitimate children, a son and a daughter, both died young. Nothing is known of the former; but the daughter resembled the father. "Fedor is a sprightly child," said the account from which we have already quoted, "and appears more intelligent than the father." The growth of down on his face is not so heavy as to conceal his features; but there is no doubt that, when the child comes to maturity, he will be at least as hirsute as his parent. The hairs are as white and as soft as the fur of the Angora cat, and are longest at the outer angles of the eyes. There is a thick tuft between the eyes, and the nose is well covered. The moustache

joins the whiskers on each side, after the English fashion, and this circumstance gives to accurate pictures of the child a ludicrous resemblance to a well-fed Englishman of about fifty. As in the father's case, the inside of Fedor's nostrils and ears has a thick crop of hair. Both father and son are almost toothless, Andrian having only five teeth, one in the upper jaw and four in the lower, while the child has only four teeth, all in the lower jaw. In both cases the four lower teeth are all incisors. To the right of Andrian's one upper tooth there still remains the mark of another which has disappeared. That beyond these six teeth the man never had any others is evident to any one who feels the gums with the finger."

The deficiency of teeth, accompanied as it is by what is in reality a deficiency, not a renundancy of hair —for Andrian and his son have no real hair—accords well with Darwin's view, that a constant correlation exists between hair and teeth. He mentions as an illustration the deficiency of teeth in hairless dogs. The tusks of the boar, again, are greatly reduced under domestication, and the reduction is accompained by a corresponding diminution of the bristles. He mentions also the case of Julia Pastrana, a Spanish dancer or opera singer, who had a thick masculine beard and a hairy forehead, while her teeth were so redundant that her mouth projected, and her face had a gorilla-like appearance. It should rather be said that, in general, those creatures which present an abnormal development in the covering of their skin, whether in the way of redundancy or deficiency, present, generally, perhaps always, an abnormal dental development, as we see in sloths and armadilloes on the one hand, which have the front teeth deficient, and in some branches of the whale family on the other, in which the teeth are redundant either in number or in size. In individual members of the human family it certainly is not always the case that the development of the hair and that of the teeth are directly correlated; for some who are bald when quite young have excellent teeth, and some who have lost most of their teeth while still on the right side of forty have excellent hair to an advanced age.*

Another case, somewhat similar to that of Andrian and his son, is found in a Burmese family, living at Ava, and first described by Crawford in 1829. Shwe-Maong, the head of the family, was about thirty years old. His whole body was covered with silky hairs, which attained a length of nearly five inches on the shoulders and spine. He had four daughters, but only one of them resembled him. She was living at Ava in 1855, and, according to the account given by a British officer who saw her there, she had a son who was hairy like his grandfather, Shwe-Maong. The case of this family illustrates rather curiously the relation between the hair and teeth. For Shwe-Maong retained his milk teeth till he was twenty years old (when he attained puberty), and they were replaced by nine teeth only, five in the upper and four in the lower jaw. Eight of these were incisors, the ninth (in the upper jaw) being a canine tooth.

Sex-digitism, or the possession of hands and feet with six digits each, has occurred in several families as a sudden variation from the normal formation, but after it has appeared has usually been transmitted for several generations. In the case of the Colburn family this peculiarity lasted

* Shakespeare, who was bald young (and, so far as one can judge from his portraits, had a good set of teeth), suggests a correlation between hairiness and want of wit, which is at least likely to be regarded by those who "wear his baldness while they're young," as a sound theory. "Why," asks Antipholus of Syracuse, "is Time such a niggard of hair, being, as it is, so plentiful an excrement?" "Because," says Dromio of Syracuse, "it is a blessing that he bestows on beasts; and what he hath scanted men in hair he hath given them in wit."

for four generations without interruption, and still reappears occasionally. In a branch of a well-known Scotch family, sex-digitism—after continuing for three or four generations—has apparently disappeared; but it still frequently happens that the edge of the hands on the side of the little finger is partially deformed.

Hare-lip, albinism, halting and other peculiarities commonly reappear for four or five generations, and are seldom altogether eradicated in less than ten or twelve.

The tendency to variation shown in the introduction of these peculiarities, even though they may have been eventually eradicated, is worth noticing in its bearing on our views respecting the formation of new and persistent varieties of the human as of other races. It must be noticed that in the case of the human race the conditions not only do not favor the continuance of such varieties, but practically forbid their persistence. It is otherwise with some varieties, at least, of domestic animals, insomuch that varieties which present any noteworthy even though accidentally observed advantage have been made practically persistent; we say practically, because there seems little reason to doubt that in every case which has hitherto been observed the normal type would eventually be reverted to if special pains were not taken to separate the normal from the abnormal form.

An excellent illustration of the difference between the human race and a race of animals under domestication, in this particular respect, is found in the case of the Kelleia family on the one hand, and that of the Ancon or Otter sheep on the other.

The former case is described by Reaumur. A Maltese couple named Kelleia, whose hands and feet were of the ordinary type, had a son, Gratio, who had six movable fingers on each hand and six somewhat less perfect toes on each foot. Gratio Kelleia married a woman possessing only the ordinary number of fingers and toes. There were four children of this marriage—Salvator, George, Andre and Marie. Salvator had six fingers and six toes like the father; George and Andre had each five fingers and five toes like the mother, but the hands and feet of George were slightly deformed; Marie had five fingers and five toes, but her thumbs were slightly deformed. All four children grew up, and married folk with the ordinary number of fingers and toes. The children of Andre alone (who were many) were without exception of the normal type, like their father. The children of Salvator, who alone was six-fingered and six-toed like Gratio, the grandfather, were four in number; three of them resembled the father, while the other—the youngest—was of the normal type like his mother and grandmother. As these four children were the descendants of four grandparents of whom one only was hexadactylic, we see that the variety had been strong enough in their case to overcome the normal type in threefold greater strength. But the strangest part of the story is that relating to George and Marie. George, who was a pentadactyle, though somewhat deformed about the hands and feet, was the father of four children; first, two girls, both purely hexadactylic; next, a girl, hexadactylic on the right side of the body and pentadactylic on the left side; and lastly, a boy, purely pentadactylic. Marie, a pentadactyle with deformed thumbs, gave birth to a boy with six toes, and three normally formed children. It will be seen, however, that the normal type showed itself in greater force than the variety in the third generation from Gratio; for while one child of Salvator's, one of George's, three of Marie's, and all of Andre's (some seven or eight) were of the normal type—twelve or thirteen in all—only five, viz., three of Salvator's and two of George's, presented the variety purely. Three others were more or less abnormally formed in fingers and toes: but even

counting these, the influence of the variety was shown only in eight of the grandchildren of Gratio, whereas twelve or thirteen were of the normal type.

The story of the Ancon or Otter sheep, as narrated by Colonel David Humphreys in a letter to Sir Joseph Banks, published in the *Philosophical Transactions* for 1813, has been thus abridged by Huxley: "It appears that one Seth Wright, the proprietor of a farm on the banks of the Charles River, in Massachusetts, possessed a flock of fifteen ewes and a ram of the ordinary kind. In the year 1791 one of the ewes presented her owner with a male lamb differing, for no assignable reason, from its parents by a disproportionately long body and short bandy legs; whence it was unable to emulate its relatives in those sportive leaps over the neighbors' fences in which they were in the habit of indulging, much to the good farmer's vexation. With the 'cuteness' characteristic of their nation, the neighbors of the Massachusetts farmer imagined it would be an excellent thing if all his sheep were imbued with the stay-at-home tendencies enforced by Nature upon the newly-arrived ram; and they advised Wright to kill the old patriarch of his fold and install the new Ancon ram in his place. The result justified their sagacious anticipations. . . . The young lambs were almost always either pure Ancons or pure ordinary sheep. But when sufficient Ancon sheep were obtained to interbreed with one another, it was found that the offspring were always pure Ancon. Colonel Humphreys, in fact, states that he was acquainted with only 'one questionable case of a contrary nature.' By taking care to select Ancons of both sexes for breeding from, it thus became easy to establish an exceedingly well-marked race—so peculiar that even when herded with other sheep, it was noted that the Ancons kept together. And there is every reason to believe that the existence of this breed might have been indefinitely protracted, but the introduction of the Merino sheep—which were not only very superior to the Ancons in wool and meat, but quite as quiet and orderly—led to the complete neglect of the new breed, so that in 1813 Colonel Humphreys found it difficult to obtain the specimen whose skeleton was presented to Sir Joseph Banks. We believe that for many years no remnant of it has existed in the United States."

It is easy, as Huxley remarks, to understand why, whereas Gratio Kelleia did not become the ancestor of a race of six-fingered and six-toed men, Seth Wright's Ancon ram became a nation of long-bodied, short-legged sheep. If the purely hexadactylic descendants of Gratio Kelleia, and all the purely hexadactylic members of the Colburn family, in the third and fourth generations, had migrated to some desert island, and had been careful not only to exclude all visitors having the normal number of fingers and toes, but to send away before the age of puberty all children of their own which might depart in any degree from the pure hexadactylic type, there can be no doubt that, under favorable conditions, the colony would have become a nation of six-fingered folk. Among such a nation the duodecimal system of notation would flourish, and some remarkable performers on the pianoforte, flute, and other instruments might be looked for; but we do not know that they would possess any other advantage over their pentadactylic contemporaries. Seeing that the system of colonizing above described is antecedently unlikely, and that no special advantage could be derived from the persistence of any hitherto known abnormal variety of the human race, it is unlikely that, for many generations yet to come, we shall hear of six-fingered, hairy-faced, horny-skinned, or hare-lipped nations. The only peculiarities which have any chance of becoming permanent are such as, while not very uncommon, stand in the way of intermarriage with persons not similarly affected. A similar re-

mark, as will presently appear, applies to mental and moral characteristics. The law according to which contrast is found attractive and similitude repugnant, though wide in its range, is not universal; and there are cases in which resemblance, if it has not the charm found (under ordinary circumstances) in contrast, is yet a necessary element in matrimonial alliances.

The inheritance of constitutional traits comes next to be considered. It is probably not less frequently observed, and is, in several respects, more interesting than the inheritance of peculiarities of bodily configuration.

Longevity, which may be regarded as measuring the aggregate constitutional energy, is well known to be hereditary in certain families, as is short duration of life in other families. The best proof that this is the case is found in the action of insurance companies, in ascertaining through their agents the longevity of the ancestors of persons proposing to insure their lives. Instances of longevity during several successive generations are too common to be worth citing. Cases in which, for generation after generation, a certain age, far short of the threescore years and ten, has not been passed, even when all the circumstances have favored longevity, are more interesting. One of the most curious among these is the case of the Turgot family, in which the age of fifty-nine had not been for generations exceeded, to the time when Turgot made the name famous. At the age of fifty, when he was in excellent health, and apparently had promise of many years of life, he expressed to his friends his conviction that the end of his life was near at hand. From that time forward he held himself prepared for death, and, as we know, he died before he had completed his fifty-fourth year.

Fecundity is associated sometimes with longevity, but in other cases it is as significantly associated with short duration of life. Of families in which many children are born, but few survive, we naturally have less striking evidence than we have of families in which many children of strong constitutions are born for several successive generations. What may be called the fecundity of the short-lived is a quality commonly leading in no long time to the disappearance of the family in which it makes its appearance. It is the reverse, of course, with fecundity in families whose members show individually great vigor of constitution and high vital power. Ribot mentions several cases of this sort among the families of the old French *noblesse*. Thus Anne de Montmorency —who, despite his feminine name, was certainly by no means feminine in character (at the Battle of St. Denis, in his sixty-sixth year, he smashed with his sword the teeth of the Scotch soldier who was giving him his death-blow) was the father of twelve children. Three of his ancestors, Matthew I., Matthew II. and Matthew III., had, in all, eighteen children, of whom fifteen were boys. "The son and grandson of the great Condé had nineteen between them, and their great-grandfather, who lost his life at Jarnac, had ten. The first four Guises reckoned in all forty-three children, of whom thirty were boys. Achille de Harley had nine children, his father ten, and his great-grandfather eighteen." In the family of the Herschels, in Hanover and in England, a similar fecundity has been shown in two generations out of three. Sir W. Herschel was one of a family of twelve children, of whom five were sons. He himself did not marry till his fiftieth year, and had only one son. But Sir John Herschel was the father of eleven children.

Of constitutional peculiarities those affecting the nervous system are most frequently transmitted. We do not, however, consider them at this point, because they are viewed ordinarily rather as they relate to mental and moral characteristics than as affec-

tions of the body. The bodily affections most commonly transmitted are those depending on what is called diathesis—a general state or disposition of the constitution predisposing to some special disease. Such are scrofula, cancer, tubercular consumption, gout, arthritis, and some diseases specially affecting the skin. It would not be desirable to discuss here this particular part of our subject, interesting though it undoubtedly is. But it may be worth while to note that we have, in the variety of forms in which the same constitutional bad quality may present itself, evidence that what is actually transmitted is not a peculiarity affecting a particular organ, even though in several successive generations the disease may show itself in the same part of the body, but an affection of the constitution generally. We have nere an answer to the question asked by Montaigne in the essay trom which we have already quoted. The essay was written soon after he had for the first time experienced the pangs of renal calculus: "'Tis to be believed," he says, "that I derived this infirmity from my father, for he died wonderfully tormented" with it; he was "never sensible of his disease till the sixty-seventh year of his age, and before that had never felt any grudging or symptom of it" . . . "but lived till then in a happy, vigorous state of health, little subject to infirmities, and continued seven years after in this disease, and dyed a very painful death. I was born about twenty-five years before his disease seized him, and in the time of his most flourishing and healthful state of body, his third child in order of birth: where could his propension to this malady lie lurking all that while? And he being so far from the infirmity, how could that small part of his substance carry away so great an impression of its share? And how so concealed that, till five-and-forty years after, I did not begin to be sensible of it? being the only one to this hour, amongst so many brothers and sisters, and all of one mother, that was ever troubled with it. He that can satisfie me in this point, I will believe him in as many other miracles as he pleases, always provided that, as their manner is, he does not give me a doctrine much more intricate and fantastic than the thing itself, for current pay." When we note, however, that in many cases the children of persons affected like the elder Montaigne are not affected like the parents, but with other infirmities, as the tendency to gout, and *vice versa* (a circumstance of which I myself have but too good reason to be cognizant, a parent's tendency to gout having in my case been transmitted in the modified but even more troublesome form of the disease which occasioned Montaigne so much anguish), we perceive that it is not "some small parts of the substance" which transmits its condition to the child, but the general state of the constitution. Moreover, it may be hoped in many cases (which would scarcely be the case if the condition or qualities of some part of the body only were transmitted) that the germs of disease, or rather the predisposition to disease, may be greatly diminished, or even entirely eradicated by suitable precautions. Thus persons inheriting a tendency to consumption have become, in many cases, vigorous and healthy by passing as much of their time as possible in the open air by avoiding crowded and over-heated rooms, taking moderate but regular exercise, judicious diet, and so forth. We believe that the disease which troubled the last fifteen years of the life of Montaigne might readily have been prevented, and the tendency to it eradicated, during his youth.

Let us turn, however, from these considerations to others more interesting, though less important, and on the whole perhaps better suited to these pages.

The inheritance of tricks or habits is one of the most perplexing of all the phenomena of heredity. The less striking the habit, the more remarkable, perhaps, is its persistence as an inherited trait. Giron de B za-

reingues states that he knew a man who, when he lay on his back, was wont to throw his right leg across the left; one of this person's daughters had the same habit from her birth, constantly assuming that position in the cradle, notwithstanding the resistance offered by the swaddling bands.* Darwin mentions another case in his *Variation of Animals and Plants Under Domestication:* A child had the odd habit of setting its fingers in rapid motion whenever it was particularly pleased with anything. When greatly excited, the same child would raise the hand on both sides as high as the eyes, with the fingers in rapid motion as before. Even in old age he experienced a difficulty in refraining from these gestures He had eight children, one of whom, a little girl, when four years of age, used to set her fingers going, and to lift up her hands after the manner of her father. A still more remarkable case is described by Galton. A gentleman's wife noticed that when he lay fast asleep on his back in bed he had the curious trick of raising his right arm slowly in front of his face, up to his forehead, and then dropping it with a jerk, so that the wrist fell heavily on the bridge of his nose. The trick did not occur every night, but occasionally, and was independent of any ascertained cause. Sometimes it was repeated incessantly for an hour or more. The gentleman's nose was prominent, and its bridge often became sore from blows which it received. At one time an awkward sore was produced that was long in healing, on account of the recurrence, night after night, of the blows which first caused it. His wife had to remove the button from the wrist of his night-gown, as it made severe scratches, and some means were attempted of tying his arm. Many years after his death, his son married a lady who had never heard of the family incident. She, however, observed precisely the same peculiarity in her husband; but his nose, from not being particularly prominent, has never as yet suffered from the blows. The trick does not occur when he is half asleep, as, for example, when he is dozing in his armchair; but the moment he is fast asleep, he is apt to begin. It is, as with his father, intermittent; sometimes ceasing for many nights, and sometimes almost incessant during a part of every night. It is performed, as it was with his father, with his right hand. One of his children, a girl, has inherited the same trick. She performs it, likewise, with the right hand, but in a slightly modified

* While penning the above lines I have been reminded of an experience of my own, which I had never before thought of as connected with the subject of heredity; yet it seems not unlikely that it may be regarded as a case in point. During the infancy of my eldest son it so chanced that the question of rest at night, and consequently the question of finding some convenient way of keeping the child quiet, became one of considerable interest to me. Cradle-rocking was effective, but, carried on in the usual way, prevented my own sleep, though causing the child to sleep. I devised, however, a way of rocking the cradle with the foot, which could be carried on in my sleep, after a few nights' practice. Now, it is an odd coincidence (only, perhaps) that the writer's next child, a girl, had, while still an infant, a trick which I have noticed in no other case. She would rock herself in the cradle by throwing the right leg over the left at regular intervals, the swing of the cradle being steadily kept up for many minutes, and being quite as wide in range as a nurse could have given. It was often continued when the child was asleep.

Since writing the above, I have learned from my eldest daughter, the girl who, as a child, had the habit described, that a recent little brother of hers, one of twins, and remarkably like her, had the same habit, rocking his own cradle so vigorously as to disturb her in the next room with the noise. These two only of twelve children have had this curious habit; but as this child is thirteen years younger than she is, the force of the coincidence in point of time is to some degree impaired.

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form; for after raising the arm, she does not allow the wrist to drop upon the bridge of the nose, but the palm of her half-closed hand falls over and down the nose, striking it rather rapidly—a decided improvement on the father's and grandfather's method. The trick is intermittent in this girl's case also, sometimes not occurring for periods of several months, but sometimes almost incessantly.

Strength in particular limbs or muscles is often transmitted hereditarily. So also is skill in special exercises. Thus in the north country there are families of famous wrestlers. Among professional oarsmen, again, we may note such cases as the Clasper family in the north, the Mackinneys in the south; while among amateur oarsmen we have the case of the Playford family, to which the present amateur champion sculler belongs. In cricket, the Walker family and the Grace family may be cited among amateurs, the Humphreys among professional players. Grace in dancing was transmitted for three generations in the Vestris family It must, however, be noted that in some of these cases we may fairly consider that example and teaching have had much to do with the result. Take rowing for instance. A good oarsman will impart his style to a whole crew if he rows stroke for them; and even if he only trains them (as Morrison, for instance, trained the Cambridge crew a few years ago), he will make good oarsmen of men suitably framed and possessing ordinary aptitude for rowing. I remember well how a famous stroke-oar at Cambridge (John Hall, of Magdalen) imparted to one at least of the University crew (a fellow-collegian of his, and therefore rowing with him constantly also in his College boat) so exact an imitation of his style that one rather dusky evening, when the latter was "stroking" a scratch four past a throng of University men, a dispute arose as to which of the two was really stroke of the four. Anyone who knows how characteristic commonly is the rowing of any first-class stroke, and still more anyone who chances to know how peculiar was the style of the University "stroke-oar" referred to, will understand how closely his style must have been adopted, when experienced oarsmen, not many yards from the passing four, were unable to decide at once which of the two men were rowing—even though the evening was dusky enough to prevent the features of the stroke (whose face was not fully in view at the moment) from being discerned. Seeing that a first-rate oarsman can thus communicate his style so perfctly to another, it cannot be regarded as demonstrably a case of hereditary transmission of the Claspers rowed in the same style as their father, or if the present champion amateur sculler (making allowances for the change introduced by the sliding seat) rows very much like his father and his uncle.

Some peculiarities, such as stammering, lisping, babbling, and the like, are not easily referable to any special class of hereditary traits, because it is not clear how far they are to be regarded as depending on bodily or how far on mental peculiarities. It might seem obvious that stammering was in most cases uncontrollable by the will, and babbling might seem as certainly controllable. Yet there are cases which throw doubt on either conclusions. Thus, Dr. Lucas tells us of a servant-maid whose loquacity was apparently quite uncontrollable. She would talk to people till they were ready to faint; and if there were no human being to listen to her, she would talk to animals and inanimate objects, or would talk aloud to herself. She had to be discharged. "But," she said to her master, "I am not to blame; it all comes from my father. He had the same fault, and it drove my mother to distraction; and his father was just the same." Stammering has been transmitted through as many as five generations. The same has been noticed of peculiarities of vision. The Montmorency look, a sort of half squint, affected

nearly all the members of the Montmorency family. The peculiarity called Daltonism, an inability to distinguish between certain colors of the spectrum, was not so named, as is often asserted, merely because the distinguished chemist Dalton was affected by it, but because three members of the same family were similarly affected. Deafness and blindness are not commonly hereditary where the parents have lost sight or hearing either by accident or through illness, even though the illness or accident occur during infancy; but persons born either blind or deaf frequently if not commonly transmit the defect to some at least among their offspring. Similar remarks apply to deaf-mutism.

The senses of taste and smell must also be included in the list of those which are affected by transmitted peculiarities. If we include the craving for liquor among such peculiarities, we might at once cite a long list of cases; but this craving must be regarded as nervo-physical, the sense of taste having in reality very little to do with it. It is doubtful how the following hideous instance should be classed. It is related by Dr. Lucas: "A man in Scotland had an irresistible desire to eat human flesh. He had a daughter; although removed from her father and mother, who were both sent to the stake before she was a year old, and although brought up among respectable people, this girl, like her father, yielded to the horrible craving for human flesh." He must be an ardent student of physiological science who regrets that, at this stage, circumstances intervened which prevented the world from ascertaining whether the peculiarity would have descended to the third and fourth generations.

Amongst the strangest cases of hereditary transmissions are those relating to handwriting. Darwin cites several curious instances in his *Variation of Plants and Animals under Domestication.* "On what a curious combination of corporeal structure, mental character, and training, he remarks, "must handwriting depend. Yet everyone must have noted the occasional close similarity of the handwriting in father and son, even although the father had not taught the son. A great collector of franks assured me that in his collection there were several franks of father and son hardly distinguishable except by their dates." Hofacker, in Germany, remarks on the inheritance of handwriting, and it has been even asserted that English boys, when taught to write in France, naturally cling to their English manner of writing. Dr. Carpenter mentions the following instance as having occurred in his own family, as showing that the character of the handwriting is independent of the special teaching which the right hand receives in this art: "A gentleman who emigrated to the United States and settled in the back-woods, before the end of last century, was accustomed, from time to time, to write long letters to his sister in England, giving an account of his family affairs. Having lost his right arm by an accident, the correspondence was temporarily kept up by one or other of his children; but in the course of a few months he learned to write with his left hand, and, before long, the handwriting of the letters thus written came to be indistinguishable from that of his former letters."

I had occasion, two or three years ago, to consider in an article on "Strange Mental Feats," in my *Science Byeways*, the question of inherited mental qualities and artistic habits, and would refer the reader for some remarkable instances of transmitted powers to that article.* Galton in his work on *Hereditary Genius*, and Ribot in his treatise on *Heredity*, have collected many facts bearing on this interesting question. Both writers show a decided bias in favor of a view which would give to heredity a rather too important position among the factors of genius. Cases are cited which seem very little

* See my *Science Byeways*, p. 337 *et seq.*

to the purpose, and multitudes of instances are omitted which oppose themselves, at a first view at any rate, to the belief that heredity plays the first part in the genesis of great minds. Nearly all the greatest names in philosophy, literature, and science, and a great number of the greatest names in art, stand absolutely alone. We know nothing achieved by the father or grandfather of Shakspeare, or of Goethe, or Schiller, or Evans (George Eliot), or Thackeray, or Dickens, or Huxley. None of Newton's family were in any way distinguished in mathematical or scientific work; nor do we know of a distinguished Laplace, or Lagrange, or Lavoisier, or Harvey, or Dalton, or Volta, or Faraday, besides those who made these names illustrious. As to general literature, page after page might be filled with the mere names of those whose ancestry have been quite undistinguished. To say that among the ancestors of Goethe, Schiller, Byron, and so forth, certain qualities, virtues or vices, passions or insensibilities to passion, may be recognized "among the ancestors of men of science, certain aptitudes for special subjects or methods of search," among the ancestors of philosophers and literary men, certain qualities or capabilities, and that such ancestral peculiarities determined the poetic, scientific or literary genius of the descendent, is in reality to little purpose, for there is probably not a single family possessing claims to culture in any civilized country among the members of which individuals might not be found with qualities thus emphasized, so to speak. Such *a posteriori* reasoning is valueless. If instances could be so classified that after carefully studying them we could make even the roughest approach to a guess respecting the cases in which a family might be expected to produce men of any particular qualities, there would be some use in these attempts at generalization; at present all that can be said is that some mental qualities and some artistic aptitudes have unquestionably in certain instances been transmitted, and that on the whole men of great distinction in philosophy, literature, science and art are rather more likely than others to have among their relations (more or less remote) persons somewhat above the average in mental or artistic qualities. But it is not altogether certain that this superiority is even quite so great as it might be expected to be if hereditary transmission played no part at all in the matter. For it cannot be denied that a great mathematician's son has rather a better chance than others of being a mathematician, a great author's son of being a writer, a great artist's son of being skillful in art, a great philosopher's son of taking philosophic views of things. Nearly every son looks forward while still young to the time when he shall be doing his father's work; nearly every father hopes, while his children are yet young, that some at least among them will follow his pursuits. The fact that so few sons of great men do follow in their fathers' footsteps shows that, despite the strong ambition of the son and the anxious hope of the father, the son, in the majority of instances, has not had ability even to take a fairly good position in the work wherein the father has been, perhaps, pre-eminently distinguished.

I have said that certain mental qualities have certainly been transmitted in some cases. Galton mentions one noteworthy instance relating to memory. In the family of Porson good memory was so notable a faculty as to give rise to the byword, "the Porson memory." Lady Hester Stanhope, says the late F. Papillon, "she whose life was so full of adventure, gives, as one among many points of resemblance between herself and her grandfather, her retentive memory. 'I have my grandfather's grey eyes,' she said, 'and his memory of places. If he saw a stone on the road, he remembered it; it is the same with myself. His eye, which was ordinarily dull and lusterless, was lighted up, like my own, with a dull gleam

whenever he was seized with passion.'"

In endeavoring to form an opinion on the law of heredity in its relation to genius, we must remember that a remark somewhat similar to one made by Huxley respecting the origin of new species applies to the origin of a man of genius. Before such a man became celebrated no one cared particularly to inquire about his ancestry or relations; when his fame was established, the time for making the inquiry had passed away. It is quite possible that, if we had exact and full information, in a great number of cases we might find the position taken up by Mr. Galton and M. Ribot greatly strengthened; it is, however, also possible that we might find it much weakened, not only by the recognition of a multitude of cases in which the approach of a great man was in no sort indicated by scintillations of brightness along the genealogical track, but by a yet greater number of cases in which families containing numbers of clever, witty and learned folks have produced none who attained real distinction.

There is an excellent remark in a thoughtful but anonymous paper on Heredity in the *Quarterly Journal of Science*, two years or so ago, which suggests some considerations well worth noting. "If we look," says the writer, "on the intellect as not a single force but a complex of faculties, we shall find little to perplex us in the phenomenon of spontaneity"—that is (in this case), in the appearance of a man of genius in a family not before remarkable in any way. "Suppose a family who have possessed some of the attributes of greatness, but who, in virtue of a principle equally true in psychology and in mechanics, that 'nothing is stronger than its weakest part' has remained in obscurity. Let a man of this family marry a woman whose faculties are the complement of his own. It is possible that a child of such a couple may combine the defects or weaknesses of both parents, and we have then the case of spontaneous imbecility or criminality. But it is also possible that he may combine the excellences of both, and burst upon the world as a spontaneous genius. . . . Again, we must remember that, even if we consider the intellect as 'one and indivisible,' it is far from being the only faculty needful for the attainment of excellence, even in the fields of pure science. Combined with it there must be the moral faculties of patience, perseverance, and concentration. The will must be strong enough to overcome all distracting temptations, whether in themselves good or evil. Lastly, there must be constitutional energy and endurance. Failing these, the man will merely leave among his friends the conviction that he might have achieved greatness, if ——. We once knew a physician, resident in a small country town, who from time to time startled his associates by some profound and suggestive idea, some brilliant *aperçu*. But a constitutional languor prevented him from ever completing an investigation, or from leaving the world one written line."

The effect of circumstances also must not be overlooked. It is certain that some of those who stand highest in the world's repute would have done nothing to make their names remembered but for circumstances which either aided their efforts or compelled them to exertion; and it cannot be doubted, therefore, that many who have been by no means celebrated have required but favoring opportunities or the spur of adverse circumstances to have achieved distinction. We note the cases in which men who have been intended by their parents for the desk or routine work have fortunately been freed for nobler work, to which their powers have specially fitted them. But we are apt to forget that for each such case there must be many instances in which no fortunate chance has intervened. The theory that genius *will* make its way, despite all obstacles, is

like the popular notion that "murder will out," and other such fancies. We note when events happen which favor such notions, but we not only do not note—in the very nature of things it is impossible that we should have the chance of noting—cases unfavorable to a notion which, after all, is but a part of the general and altogether erroneous idea that what we think ought to be, will be. That among millions of men in a civilized community, trained under multitudinous conditions, for diverse professions, trades, and so forth, exposed to many vicissitudes of fortune, good and bad, there should be men from time to time

Who break their birth's invidious bar,
And grasp the skirts of happy chance,
And breast the blows of circumstance,
And grapple with their evil star,

is no truer proof of the general theory that genius will make its mark, despite circumstance, than is the occasional occurrence of strange instances in which murder has been detected despite seemingly perfect precautions.

It must, however, be in a general sense admitted that mental powers, like bodily powers, are inherited. If the ancestry of men of genius could be traced, we should in each case probably find enough, in the history of some line at least along which descent could be traced, to account for the possession of special powers, and enough in the history of that and other lines of descent to account for the other qualities or characteristics which, combined with those special powers, gave to the man's whole nature the capacity by which he was enabled to stand above the average level of his fellow-men. We might, with knowledge at once wider and deeper than we actually possess of the various families of each nation, and their relationships, predict in many cases, not that any given child would prove a genius, but that some one or other of a family would probably rise to distinction. To predict the advent of a man of great genius as we predict the approach of an eclipse or a transit, will doubtless never be in men's power; but it is conceivable that at some perhaps not very remote epoch, anticipations may be formed somewhat like those which astronomers are able to make respecting the recurrence of meteoric showers at particular times and seasons, and visible in particular regions. Already we know so much as this, that in certain races of men only can special forms of mental energy, like special bodily characteristics, be expected to appear. It may well be that hereafter such anticipations may be limited to special groups of families.

When we pass from mental to moral qualities we find ourselves in the presence of problems which could not be thoroughly dealt with in these pages. The general question, how far the moral characteristics of each person born into the world depends on those of the parents, or more generally of the ancestry, is one involving many considerations which, perhaps unfortunately, have been associated with religious questions. And apart from this, the answers to this question have been found to have a very wide range—from the opinion of those who (like Miss Martineau) consider that our characters, even where they seem to undergo changes resulting from the exercise of will, are entirely due to inheritance, to the view of those who consider, like Heinroth, that no moral characteristic can possibly be regarded as inherited in such sort as to modify either responsibility for evil-doing or credit for well-doing. Probably most will be content to accept a view between these extremes, without too nicely considering how far moral responsibility is affected by the influence of inherited tendencies.

There are, however, some illustrations relating to exceptional habits, which may be mentioned here without bringing in the general question.

I have not referred to insanity in speaking of inherited mental qualities, because insanity must be regarded as

a disease of the moral rather than of the mental nature. Its origin may be in the mind, as the origin of mental diseases is in the brain, that is, is in the body; but the principal manifestations of insanity, those which must guide us in determining its true position, are unquestionably those relating to moral habitudes. Insanity is not always, or at least not always demonstrably, hereditary. Esquirol found among 1,375 lunatics 337 unquestionable cases of hereditary transmission. Guislain and others regard hereditary lunacy as including, roughly, one-fourth of the cases of insanity. Moreau and others hold that the proportion is greater. It appears, however, that mental alienation is not the only form in which the insanity of an ancestor may manifest itself. Dr. Morel gives the following instructive illustration of the "varied and odd complications occurring in the hereditary transmissions of nervous disease." He attended four brothers belonging to one family. The grandfather of these children had died insane; their father had never been able to continue long at anything; their uncle, a man of great intellect and a distinguished physican, was noted for his eccentricities. Now, these four children, sprung from one stock, presented very different forms of physical disorder. One of them was a maniac, whose wild paroxysms occurred periodically. The disorder of the second was melancholy madness; he was reduced by his stupor to a merely automatic condition. The third was characterized by an extreme irascibility and suicidal disposition. The fourth manifested a strong liking for art; but he was of a timorous and suspicious nature. This story seems, in some degree, to give support to the theory that genius and mental aberration are not altogether alien; that, in fact,

Great wit to madness nearly is allied,
And thin partitions do their bounds divide.

Of the hereditary transmission of idiotcy we naturally have not the same kind of evidence. Madness often, if not generally, comes on or shows itself late in life, whereas idiotcy is not often developed in the adult. Insanity is the diseased or weakened condition of a mind possessing all the ordinary thinking faculties; idiotcy implies that some of these faculties are altogether wanting. It has been asserted, by the way, that idiotcy is a production of civilization. The civilized "present, as peoples," says Dr. Duncan, "indications of defective vital force, which are not witnessed among those human beings that live in a state of nature. There must be something rotten in some parts of our boasted civilization: and not only a something which has to do with our psychology, but a great deal more with our power of physical persistence. It is a fact that the type of the perfect minded, just above the highest idiots, or the simpletons, is more distinguishable amongst the most civilized of the civilized than among those who are the so-called children of nature. Dolts, boobies, stupids, *et hoc genus omne*, abound in young Saxondom; but their representatives are rare amongst the tribes that are slowly disappearing before the white man." But it seems barely possible that the difference may be due to the care with which civilized communities interfere to prevent the elimination of idiot infants by the summary process of destroying them. The writer from whom I have just quoted refers to the fact that, even under the Roman Empire, as during the Republic, idiots were looked upon as "useless entities by the practical Roman." They had no sanctity in his eyes, and hence their probable rarity; doubtless the unfortunate children were neglected, and there is much reason for believing that they were "exposed." "A congenital idiot soon begins to give trouble," proceeds Dr. Duncan, "and to excite unusual attention; and, moreover, unless extra care is given to it, death is sure to ensue in early childhood." May not

idiot children in savage communities have an even worse chance of survival than under the Roman Empire? and may not dolts, boobies, and stupids, *et hoc genus omne*, among savages, have such inferior chances in the infantine and later in the adult struggle for existence, that we may explain thus the comparative rarity of these varieties in savage communities? It certainly does not seem to have been proved as yet that civilization *per se* is favorable to the development of insanity.

The liking for strong drink, as is too well known, is often transmitted. It is remarked by Dr. Howe that "the children of drunkards are deficient in bodily and vital energy, and are predisposed by their very organization to have cravings for alcoholic stimulants. If they pursue the course of their fathers, which they have more temptation to follow and less power to avoid than the children of the temperate, they add to their hereditary weakness, and increase the tendency to idiotcy or insanity in their constitution; and this they leave to their children after them." Whatever opinion we may form on the general question of responsibility for offences of commission or of omission, on this special point all who are acquainted with the facts must agree, admitting that, in some cases of inherited craving for alcoholic stimulants, the responsibility of those who have failed and fallen in the struggle has been but small. "The fathers have eaten sour grapes, and the children's teeth are set on edge." Robert Collyer, of Chicago, in his noble sermon "The Thorn in the Flesh" has well said: "In the far-reaching influences that go to every life, and away backward as certainly as forward, children are sometimes born with appetites fatally strong in their nature. As they grow up the appetite grows with them, and speedily becomes a master, the master a tyrant; and by the time he arrives at manhood, the man is a slave. I heard a man say that for eight-and-twenty years the soul within him had had to stand like an unsleeping sentinel, guarding his appetite for strong drink. To be a man at last under such a disadvantage, not to mention a saint, is as fine a piece of grace as can well be seen. There is no doctrine that demands a larger vision than this of the depravity of human nature. Old Dr. Mason used to say that 'as much grace as would make John a saint, would hardly keep Peter from knocking a man down.'"

There are some curious stories of special vices transmitted from parent to child, which, if true, are exceedingly significant, to say the least.* Gama Machado relates that a lady with whom he was acquainted, who possessed a large fortune, had a passion for gambling and passed whole nights at play. "She died young," he proceeds, "of a pulmonary complaint. Her eldest son, who was in appearance the image of his mother, had the same passion for play. He died of consumption like his mother, and at the same age; his daughter, who resembled him, inherited the same tastes and died young." Hereditery predisposition to theft, mur-

* The following statement from the researches of Brown-Sequard seems well worth noting in this connection: "In the course of his masterly experimental investigations into the functions of the nervous system he discovered that, after a particular lesion of the spinal cord of guinea-pigs, a slight pinching of the skin of the face would throw the animal into a kind of epileptic convulsion. That this artificial epilepsy should be constantly producible in guinea-pigs, and not in any other animals experimented on, was in itself sufficiently singular; and it was not less surprising that the tendency to it persisted after the lesion of the spinal cord seemed to have been entirely recovered from. But it was far more wonderful that the offspring of these epileptic guinea-pigs showed the same predisposition without having been themselves subjected to any lesion whatever; whilst no such tendency showed itself in any of the large number of young bred by the same accurate observer from parents that had not thus been operated on."

der and suicide, has been demonstrated in several cases. But the world at large is naturally indisposed to recognise congenital tendency to crime as largely diminishing responsibility for offences or attempted offences of this kind. So far as the general interests of the community are concerned, the demonstrated fact that a thief or murderer has *inherited* his unpleasant tendency should be a *raison de plus* for preventing the tendency from being transmitted any farther. In stamping out the hereditary ruffian or rascal by life imprisonment, we not only get rid of the "grown serpent," but of the worm which

> Hath nature that in time would venom breed.

An illustration of the policy at least (we do not say the justice) of preventive measures in such cases, is shown in the case of a woman in America, of whom the world may fairly say what Father Paul remarked to gentle Alice Brown, it "never knew so criminal a family as hers." A young woman of remarkably depraved character infested, some seventy years since, the district of the Upper Hudson. At one stage of her youth she narrowly, and somewhat unfortunately, escaped death. Surviving, however, she bore many children, who in turn had large families, insomuch that there are now some eighty direct descendants, of whom one-fourth are convicted criminals, whilst the rest are drunkards, lunatics, paupers, and otherwise undesirable members of the community.

With facts such as these before us, we cannot doubt that in whatever degree variability may eliminate after awhile peculiar mental or moral tendencies, these are often transmitted for many generations before they die out. If it be unsafe to argue that the responsibility of those inheriting special characteristics is diminished, the duties of others towards them may justly be considered to be modified. Other duties than the mere personal control of tendencies which men may recognize in themselves are also introduced. If a man finds within himself an inherent tendency towards some sin, which yet he utterly detests, insomuch that while the spirit is willing the flesh is weak, or perchance utterly powerless, he must recognize in his own life a struggle too painful and too hopeless to be handed down to others. As regards our relations to families in which criminal tendencies have been developed, either through the negligence of those around (as in certain dens in London where, for centuries, crime has swarmed and multiplied), or by unfortunate alliances, we may "perceive here a divided duty." It has been remarked that "we do not set ourselves to train tigers and wolves into peaceful domestic animals; we seek to extirpate them," and the question has been asked, "why should we act otherwise with beings, who, if human in form, are worse than wild beasts?" "To educate the son of a garroter or 'corner-man' into an average Englishman" may be "about as promising a task as to train one of the latter into a Newton or a Milton." But we must not too quickly despair of a task which may be regarded as a duty inherited from those who in past generations neglected it.

There is no hope of the reversion of tiger or wolf to less savage types, for, far back as we can trace their ancestry, we find them savage of nature. With our criminal families the case is not so utterly hopeless. Extirpation being impossible (though easily talked of) without injustice, which would be the parent of far greater troubles even than our criminal classes bring upon us, we should consider the elements of hope which the problem undoubtedly affords. By making it the manifest interest of our criminal population to scatter, or, failing that, by leaving them no choice in the matter, the poison in their blood may before many generations be eradicated, not by wide-spreading merely, but because of the circumstance that only the better sort among them would have (when scattered) much chance of rearing families as well as of escaping imprisonment.

II.

ARTIFICIAL SOMNAMBULISM.

Rather more than a quarter of a century ago, two Americans visited London, who called themselves professors of Electro-Biology, and claimed the power of "subjugating the most determined wills, paralyzing the strongest muscles, preventing the evidence of the senses, destroying the memory of the most familiar events or of the most recent occurrences, inducing obedience to any command, and making an individual believe himself transformed into any one else.* All this and more was to be effected, they said, by the action of a small disc of zinc and copper held in the hand of the "subject," and steadily gazed at by him, "so as to concentrate the electro-magnetic action." The pretensions of these professors received before long a shock as decisive as that which overthrew the credit of the professors of animal magnetism when Haygarth and Falconer successfully substituted wooden tractors for the metallic tractors which had been supposed to convey the magnetic fluid In 1851, Mr. Braid, a Scotch surgeon, who had witnessed some of the exhibitions of the electro-biologists, conceived the idea that the phenomena were not due to any special qualities possessed by the discs of zinc and copper, but simply to the fixed look of the "subject" and the entire abstraction of his attention. The same explanation applied to the so-called "magnetic passes" of the mesmerists. The monotonous manipulation of the operator produced the same effect as the fixed stare of the "subject." He showed by his experiments that no magnetizer, with his imaginary secret agents or fluids, is in the least wanted; but that the subjects can place themselves in the same condition as the supposed subjects of electro-biological influences by simply gazing fixedly at some object for a long time with fixed attention.

The condition thus superinduced is not hypnotism, or artificial somnambulism, properly so called. "The electro-biological" condition may be regarded as simply a kind of reverie or abstraction artificially produced. But Braid discovered that a more perfect control might be obtained over "subjects," and a condition resembling that of the sleep-walker artificially induced, by modifying the method of fixing the attention. Instead of directing the subject's gaze upon a bright object, placed at a considerable distance from the eyes, so that no effect was required to concentrate vision upon it, he placed a bright object somewhat above and in front of the eyes at so short a distance that the convergence of their axes upon it was accompanied with sufficient effect to produce even a slight amount of pain. The condition to which the "subjects" of this new method were reduced was markedly different from the ordinary "electro-biological" state. Thus on one occasion, in the presence of 800 persons, fourteen men were experimented upon. "All began the experiment at the same time; the former with their eyes fixed upon a projecting cork, placed securely on their foreheads; the others at their own will gazed steadily at certain points in the direction of the audience. In the course of ten minutes the eyelids of these ten persons had involuntarily closed. With some, consciousness remained; others were in catalepsy, and entirely insensible to being stuck with needles; and others on awakening knew absolutely nothing of what had taken place during their sleep." The other four simply passed into the ordinary condition of electro-biologized "subjects," retaining the recollection of all that happened to them while in the state of artificial abstraction or reverie.

Dr. Carpenter, in that most interesting work of his, "Mental Physiology," thus describes the state of hypnotism: "The process is of the same kind as that employed for the induction of the 'biological' state, the only difference lying in the *greater*

intensity of the gaze, and in the more complete concentration of will upon the direction of the eyes, which the nearer approximation of the object requires for the maintenance of the convergence. In hypnotism, as in ordinary somnambulism, no remembrance whatever is preserved in the waking state of anything that may have occurred during its continuance; although the previous train of thought may be taken up and continued uninterruptedly on the next occasion that the hypnotism is induced. And when the mind is not excited to activity by the stimulus of external impressions, the hypnotized subject appears to be profoundly asleep; a state of torpor, in fact, being usually the first result of the process, and any subsequent manifestation of activity being procurable only by the prompting of the operator. The hypnotized subject, too, rarely opens his eyes; his bodily movements are usually slow; his mental operations require a considerable time in their performance; and there is altogether an appearance of heaviness about him, which contrasts strongly wtih the comparatively wide-awake air of him who has not passed beyond the ordinary 'biological' state."

We must note, however, in passing, that the condition of complete hypnotism had been obtained in several instances by some of the earlier experimenters in animal magnetism. One remarkable instance was communicated to the surgical section of the French Academy on April 16, 1829, by Jules Cloquet. Two meetings were entirely devoted to its investigation. The following account presents all the chief points of the case, surgical details being entirely omitted, however, as not necessary for our present purpose: A lady, aged sixty-four, consulted M. Cloquet on April 8, 1829, on account of an ulcerrated cancer of the right breast, which had continued gradually growing worse, during several years. M. Chapelain, the physician attending the lady, had "magnetized" her for some months, producing no remedial effects, but only a very profound sleep or torpor, during which all sensibility seemed to be annihilated, while the ideas retained all their clearness. He proposed to M. Cloquet to operate upon her while she was in this state of torpor, and the latter, considering the operation the only means of saving her life, consented. The two doctors do not appear to have been troubled by any scruples as to their right thus to conduct an operation to which, when in her normal condition, the patient strenuously objected. It sufficed for them that when they had put her to sleep artificially, she could be persuaded to submit to it. On the appointed day M. Cloquet found the patient ready "dressed and seated in an elbow-chair, in the attitude of a person enjoying a quiet, natural sleep." In reality, however, she was in the somnambulistic state, and talked calmly of the operation. During the whole time that the operation lasted—from ten to twelve minutes—she continued to converse quietly with M. Cloquet, "and did not exhibit the slightest sign of sensibility. There was no motion of the limbs or of the features, no change in the respiration nor in the voice; no motions even in the pulse. The patient continued in the same state of automatic indifference and impassibility in which she had been some minutes before the operation." For forty-eight hours after this, the patient remained in the somnambulistic state, showing no sign of pain during the subsequent dressing of the wound. When awakened from this prolonged sleep she had no recollection of what had passed in the interval; "but on being informed of the operation, and seeing her children around her, she experienced a very lively emotion, which the 'magnetiser' checked by immediately setting her asleep." Certainly none of the hypnotized "subjects" of Mr. Braid's experiments showed more complete abstraction from their normal condition than this lady; and other cases cited in Bertrand's work,

"Le Magnétisme Animal en France" (1826), are almost equally remarkable. As it does not appear that in any of these cases Braid's method of producing hypnotism by causing the eyes, or rather their optical axes, to be converged upon a point, was adopted, we must conclude that this part of the method is not absolutely essential to success. Indeed, the circumstance that in some of Braid's public experiments numbers of the audience became hypnotized without his knowledge, shows that the more susceptible "subjects" do not require to contemplate a point near and slightly above the eyes, but may be put into the true hypnotic state by methods which, with the less susceptible, produce only the electro-biological condition.

It will be well, however, to inquire somewhat carefully into this point. My present object, I would note, is not merely to indicate the remarkable nature of the phenomena of hypnotism, but to consider these phenomena with direct reference to their probable cause. It may not be possible to obtain a satisfactory explanation of them. But it is better to view them as phenomena to be accounted for than merely as surprising but utterly inexplicable circumstances.

Now we have fortunately the means of determining the effect of the physical relations involved in these experiments, apart from those which are chiefly due to imagination. For animals can be hypnotised, and the conditions necessary for this effect to be fully produced have been ascertained.

The most familiar experiment of this sort is sometimes known as Kircher's. Let the feet of a hen be tied together (though this is not necessary in all cases), and the hen placed on a level surface. Then, if the body of the hen is gently pressed down, the head extended. with the beak pointing downwards, touching the surface on which the hen stands, and a chalk mark is drawn slowly along the surface, from the tip of the beak in a line extending directly from the bird's eye, it is found that the hen will remain for a considerable time perfectly still, though left quite free to move. She is, in fact, hypnotized.

We have now to inquire what parts of the process just described are effective in producing the hypnotic condition, or whether all are essential to success in the experiment.

In the first place, the fastening of the feet may be dispensed with. But it has its influence, and makes the experiment easier. An explanation, or rather an illustration, of its effect is afforded by a singular and interesting experiment devised by Lewissohn, of Berlin: If a frog is placed on its back, it immediately, when the hand which had held it is removed, turns over and escapes. But if the two fore legs are tied with a string, the frog, when placed on its back, breathes heavily, but is otherwise quite motionless, and does not make the least attempt to escape, even when the experimenter tries to move it. "It is as though," says Czermak, describing the experiment as performed by himself, "its small amount of reasoning power had been charmed away, or else that it slept with open eyes. Now I press upon the cutaneous nerves of the frog, while I loosen and remove the threads on the fore legs. Still the animal remains motionless upon its back, in consequence of some remaining after-effect; at last, however, it returns to itself, turns over and quickly escapes."

Thus far the idea suggested is that the animal is so affected by the cutaneous pressure as to suppose itself tied and therefore unable to move. In other words, this experiment suggests that imagination acts on animals as on men, only in a different degree. I may cite here a curious case which I once noticed and have never been able to understand, though it seems to suggest the influence of imagination on an animal one would hardly suspect of being at all under the influence of any but purely physical influences. Hearing a noise as of a cat leaping down from a pantry

window, which looked out on an enclosed yard, I went directly into the yard, and there saw a strange cat running off with a fish she had stolen. She was at the moment leaping on to a bin, from the top of which, by another very easy leap, she could get on to the wall enclosing the yard, and so escape. With the idea rather of frightening her than hurting her (does one missile out of a hundred flung at cats ever hit them?), I threw at the thief a small piece of wood which I had in my hand at the moment. It struck the wall above her just as she was going to leap to the top of the wall, and it fell, without touching her, between her and the wall. To my surprise, she stood perfectly still, looking at the piece of wood, her mouth, from which the fish had fallen, remaining open, and her whole attitude expressing stupid wonder. I make no doubt I could have taken her prisoner, or struck her heavily, if I had wished, for she made no effort to escape until, with a parlor broom which stood by, I pushed her long the top of the bin toward the wall, when she seemed suddenly to arouse herself, and leaping to the top of the wall, she made off. My wife witnessed the last scene of this curious little comedy. In fact, it was chiefly, perhaps, because she pleaded for mercy on "the poor thing" that the soft end of the broom alone came into operation; for, though not altogether agreeing with the Count of Roussillon that anything can be endured before a cat, I did not at the moment regard that particular cat with special favor.

The extension of the neck and depression of the head in the experiment with the hen have no special significance, for Czermak has been able to produce the same phenomena of hypnotism without them, and has failed to produce the hypnotic effect on pigeons when attending to this point, and in other respects proceeding as nearly as possible in the same way as with hens. "With the hens," he says, "I often hung a piece of twine, or a small piece of wood, directly over their crests, so that the end fell before their eyes. The hens not only remained perfectly motionless, but closed their eyes, and slept with their heads sinking until they came in contact with the table. Before falling asleep, the hens' heads can be either pressed down or raised up, and they will remain in this position as if they were pieces of wax. That is, however, a symptom of a cataleptic condition, such as is seen in human beings under certain pathological conditions of the nervous system."

On the other hand, repeated experiments convinced Czermak that the pressure on the animal as it is held is of primary importance. It is frequently the case, he says, that a hen, which for a minute has been in a motionless state, caused by simply extending the neck and depressing the head, awakes and flies away, but on being caught again immediately, she can be placed once more in the condition of lethargy, if we place the animal in a squatting position, and overcome with gentle force the resistance of the muscles, by firmly placing the hand upon its back. During the slow and measured suppression, one often perceives an extremely remarkable position of the head and neck, which are left entirely free. The head remains as if held by an invisible hand in its proper place, the neck being stretched out of proportion, while the body by degrees is pushed downwards. If the animal is thus left entirely free, it remains for a minute or so in this peculiar condition with wide-open staring-eyes. "Here," as Czermak remarks, "the actual circumstances are only the effect of the emotion which the nerves of the skin excite, and the gentle force which overcomes the animal's resistance. Certainly the creature a short time before had been in a condition of immobility, and might have retained some special inclination to fall back into the same, although the awakening, flight, and recapture, together with the refreshment given to the nervous system, are

intermediate circumstances." Similar experiments are best made upon small birds. Now, it is well known to bird-fanciers that goldfinches, canary-birds, etc., can be made to remain motionless for some time by simply holding them firmly for a moment and then letting them go. "Here, in my hand," said Czermak, in his lecture, "is a timid bird, just brought from market. If I place it on its back, and hold its head with my left hand, keeping it still for a few seconds, it will lie perfectly motionless after I have removed my hands, as if charmed, breathing heavily, and without making any attempt to change its position or to fly away." ("Two of the birds," says the report, "were treated in this manner without effect; but the third, a siskin, fell into a sleeping condition, and remained completely immovable on its back, until pushed with a glass tube, when it awoke and flew actively around the room.")

Also when a bird is in a sitting position, and the head is pressed slightly back, the bird falls into a sleeping condition, even though the eyes had been open. "I have often noticed," says Czermak, "that the birds under these circumstances close their eyes for a few minutes or even a quarter of an hour, and are more or less fast asleep."

Lastly, as to the chalk-line in Kircher's experiment. Czermak found, as already said, that pigeons do not become motionless, as happens to hens, if merely held firmly in the hand, and their heads and necks pressed gently on the table. Nor can they be hypnotized like small birds in the experiment last mentioned. "That is," he says, "I held them with a thumb placed on each side of the head, which I bent over a little, while the other hand held the body gently pressed down upon the table; but even this treatment, which has such an effect on little birds, did not seem to succeed at first with the pigeons; almost always they flew away as soon as I liberated them and entirely removed my hands." But he presently noticed that the short time during which the pigeons remained quiet lengthened considerably when the finger only of the hand which held the head was removed. Removing the hand holding the body made no difference, but retaining the other hand near the bird's head, the hand made all the difference in the world. Pursuing the line of research thus indicated, Czermak found to his astonishment that the fixing of the pigeon's look on the finger placed before its eyes was the secret of the matter. In order to determine the question still more clearly, he tried the experiment on a pigeon which he had clasped firmly by the body in his left hand, but whose neck and head were perfectly free. "I held one finger of my right hand steadily before the top of its beak—and what did I see? The first pigeon with which I made this attempt remained rigid and motionless, as if bound, for several minutes, before the outstretched finger of my right hand! Yes, I could take my left hand, with which I had held the bird, and again touch the pigeon without waking it up; the animal remained in the same position while I held my outstretched finger still pointing towards the beak." "The lecturer," says the report, "demonstrated this experiment in the most successful manner with a pigeon which was brought to him."

Yet it is to be noticed that among animals, as among men, different degrees of subjectivity exist. "Individual inward relations," says Czermak, "as well as outward conditions, must necessarily exercise some disturbing influence, whether the animal will give itself up to the requisite exertions of certain parts of its brain with more or less inclination or otherwise. We often see, for example, that a pigeon endeavors to escape from confinement by a quick turning of its head from side to side. In following those singular and characteristic movements of the head and neck, with the finger held before the bird, one either gains his point, or else makes the pigeon so perplexed and excited that it at last

becomes quiet, so that, if it is held firmly by the body and head, it can be forced gently down upon the table. As Schopenhauer says of sleeping, "The brain must bite." I will also mention here, by the way, that a tame parrot, which I have in my house, can be placed in this sleepy condition by simply holding the finger steadily before the top of its beak."

I may cite here a singular illustration of the effect of perplexity in the case of a creature in all other respects much more naturally circumstanced than the hens, pigeons, and small birds of Czermak's experiments. In the Spring of 1859, when I was an undergraduate at Cambridge, I and a friend of mine were in canoes on the part of the Cam which flow through the College grounds. Here there are many ducks and a few swans. It occurred to us, not, I fear, from any special scientific spirit, but as a matter of curiosity, to inquire whether it was possible to pass over a duck in a canoe. Of course on the approach of either canoe a duck would try to get out of the way on one side or the other; but on the course of the canoe being rapidly changed, the duck would have to change his course. Then the canoe's course would again be changed, so as to compel the duck to try the other side. The canoe drawing all the time nearer, and her changes of course being made very lightly and in quicker and quicker alteration as she approached, the duck would generally get bewildered, and finally would allow the canoe to pass over him, gently pressing him under water in its course. The process, in fact, was a sort of mild keel hauling. The absolute rigidity of body and the dull stupid stare with which some of the ducks met their fate seems to me (*now:* I was not in 1859 familiar with the phenomena of hypnotism) to suggest that the effect was to be explained as Czermak explains the hypnotism of the pigeons on which he experimented.

We shall be better able now to understand the phenomena of artificial somnambulism in the case of human beings. If the circumstances observed by Kircher, Czermak, Lewissohn, and others suggest, as I think they do, that animal hypnotism is a form of the phenomenon sometimes called fascination, we may be led to regard the possibility of artificial somnambulism in men as a survival of a property playing in all probability an important and valuable part in the economy of animal life. It is in this direction, at present, that the evidence seems to tend.

The most remarkable circumstance about the completely hypnotized subject is the seemingly complete control of the will of the "subject" and even of his opinions. Even the mere suggestions of the operator, not expressed verbally or by signs, but by movements imparted to the body of the subject, are at once responded to, as though, to use Dr. Garth Wilkinson's expression, the *whole man* were given to each perception. Then, "if the hand be placed," says Dr. Carpenter, "upon the top of the head, the somnambulist will frequently, of his own accord, draw up his body to its fullest height, and throw his head slightly back; his countenance then assumes an expression of the most lofty pride, and his whole mind is obviously possessed by that feeling. When the first action does not of itself call forth the rest, it is sufficient for the operator to straighten the legs and spine, and to throw the head somewhat back, to arouse that feeling and the corresponding expression to its fullest intensity. During the most complete domination of this emotion, let the head be bent forward, and the body and limbs gently flexed; and the most profound humility then instantaneously takes its place." Of course in some cases we may well believe that the expressions thus described by Dr. Carpenter have been simulated by the subject. But there can be no reason to doubt the reality of the operator's control in many cases. Dr. Carpenter says that he has not only been an eye-witness of them on various occasions, but that

he places full reliance on the testimony of an intelligent friend, who submitted himself to Mr. Braid's manipulations, but retained sufficient self-consciousness and voluntary power to endeavor to exercise some resistance to their influence at the time, and subsequently to retrace his course of thought and feeling. "This gentleman declares," says Dr. Carpenter, "that, although accustomed to the study of character and to self-observation, he could not have conceived that the whole mental state should have undergone so instantaneous and complete a metamorphosis, as he remembers it to have done, when his head and body were bent forward in the attitude of humility, after having been drawn to their full height in that of self-esteem."

A most graphic description of the phenomena of hypnotism is given by Dr. Garth Wilkinson: "The preliminary state is that of abstraction, produced by fixed gaze upon some unexciting and empty thing (for poverty of object engenders abstraction), and this abstraction is the logical premiss of what follows. Abstraction tends to become more and more abstract, narrower and narrower; it tends to unity and afterwards to nullity. There, then, the patient is, at the summit of attention, with no object left, a mere statue of attention, a listening, expectant life; a perfectly undistracted faculty, dreaming of a lessening and lessening mathematical point; the end of his mind sharpened away to nothing. What happens? Any sensation that appeals is met by this brilliant attention, and receives its diamond glare; being perceived with a force of leisure of which our distracted life affords only the rudiments. External influences are sensated, sympathized with, to an extraordinary degree; harmonious music sways the body into graces the most affecting; discords jar it, as though they would tear it limb from limb. Cold and heat are perceived with similar exaltation; so also smells and touches. In short, *the whole man appears to be given to each perception.* The body trembles like down with the wafts of the atmosphere; the world plays upon it as upon a spiritual instrument finely attuned."

This state, which may be called the natural hypnotic state, may be artificially modified. "The power of suggestion over the patient," says Dr. Garth Wilkinson, "is excessive. If you say, 'What animal is it?' the patient will tell you it is a lamb, or a rabbit, or any other. 'Does he see it?' 'Yes.' 'What animal is it *now?*' putting depth and gloom into the tone of *now*, and thereby suggesting a difference. 'Oh!' with a shudder, 'it is a wolf.' 'What color is it?' still glooming the phrase. 'Black.' 'What color is it now?' giving the *now* a cheerful air. 'Oh! a beautiful blue!' (rather an unusual color for a wolf, I would suggest), spoken with the utmost delight (and no wonder! especially if the hypnotic subject were a naturalist). And so you lead the subject through any dreams you please, by variations of questions and of inflections of the voice! and *he sees and feels all as real.*"

We have seen how the patient's mind can be influenced by changing the posture of his body. Dr. Wilkinson gives very remarkable evidence on this point. "Double his fist and pull up his arm, if you dare," he says of the subject, "for you will have the strength of your ribs rudely tested. Put him on his knees and clasp his hands, and the saints and devotees of the artists will pale before the trueness of his devout actings. Raise his head while in prayer, and his lips pour forth exulting glorifications, as he sees heaven opened, and the majesty of God raising him to his place; then in a moment depress the head, and he is in dust and ashes, an unworthy sinner, with the pit of hell yawning at his feet. Or compress the forehead, so as to wrinkle it vertically, and thorny-toothed clouds contract in from the very horizon" (in the subject's imagination, it will be understood); "and what is

remarkable, the smallest pinch and wrinkle, such as will lie between your nipping nails, is sufficient nucleus to crystalize the man into that shape, and to make him all foreboding, as, again, the smallest expansion in a moment brings the opposite state, with a full breathing of delight."

Some will perhaps think the next instance the most remarkable of all, perfectly natural though one-half of the performance may have been. The subject being a young lady, the operator asks whether she or another is the prettier, raising her head as he puts the question. "Observe," says Dr. Wilkinson, "the inexpressible hauteur, and the puff sneers let off from the lips" (see Darwin's treatise on the "Expression of the Emotions," plate IV. 1, and plate V. 1), "which indicate a conclusion too certain to need utterance. Depress the head, and repeat the question, and mark the self-abasement with which she now says '*She is*,' as hardly worthy to make the comparison."

In this state, in fact, "whatever posture of any passion is induced, the passion comes into it at once, and dramatizes the body accordingly."

It might seem that there must of necessity be some degree of exaggeration in this description, simply because the power of adequately expressing any given emotion is not possessed by all. Some can in a moment bring any expression into the face, or even simulate at once the expression and the aspect of another person, while many persons, probably most, possess scarcely any power of the sort, and fail ridiculously even in attempting to reproduce the expressions corresponding to the commonest emotions. But it is abundantly clear that the hypnotized subject possesses for the time being abnormal powers. No doubt this is due to the circumstance that for the time being "the whole man is given to each perception." The stories illustrative of this peculiarity of the hypnotized state are so remarkable that they have been rejected as utterly incredible by many who are not acquainted with the amount of evidence we have upon this point.

The instances above cited by Dr. Garth Wilkinson, remarkable though they may be, are surpassed altogether in interest by a case which Dr. Carpenter mentions: of a factory girl whose musical powers had received little cultivation, and who could scarcely speak her own language correctly, who nevertheless exactly imitated both the words and the music of vocal performances by Jenny Lind. Dr. Carpenter was assured by witnesses in whom he could place implicit reliance, that this girl, in the hypnotized state, followed the Swedish nightingale's songs in different languages "so instantaneously and correctly, as to both words and music, that it was difficult to distinguish the two voices. In order to test the powers of the somnambulist to the utmost, Mademoiselle Lind extemporized a long and elaborate chromatic exercise, which the girl imitated with no less precision, though in her waking state she durst not even attempt anything of the sort."

The exaltation of the senses of hypnotized subjects is an equally wonderful phenomenon. Dr. Carpenter relates many very remarkable instances as occurring within his own experience. He has "known a youth, in the hypnotized state," he says, "to find out by the sense of smell, the owner of a glove which was placed in his hand from amongst a party of more than sixty persons, scenting at each of them one after the other until he came to the right individual. In another case, the owner of a ring was unhesitatingly found out from amongst a company of twelve, the ring having been withdrawn from the finger before the somnambule was introduced." The sense of touch has, in other cases, been singularly intensified, insomuch that slight differences of heat, which to ordinary feeling were quite inappreciable, would be at once detected, while such differences as can be but just per

ceived in the ordinary state would produce intense distress.

In some respects the increase of muscular power, or rather of the power of special muscles, is even more striking, because it is commonly supposed by most persons that the muscular power depends entirely on the size and quality of the muscles, the state of health, and like conditions, not on the imagination. Of course every one knows that the muscles are capable of greater efforts when the mind is much excited by fear and other emotions. But the general idea is, I think, that whatever the body is capable of doing under circumstances of great excitement, it is in reality capable of doing at all times if only a resolute effort is made. Nor is it commonly supposed that a very wide difference exists between the greatest efforts of the body under excitement and those of which it is ordinarily capable. Now, the condition of the hypnotized subject is certainly not one of excitement. The attempts which he is directed to make are influenced only by the idea that he *can* do what he is told, not that he *must* do so. When a man pursued by a bull leaps over a wall, which, under ordinary conditions, he would not even think of climbing, we can understand that he only does because he must, what if he liked he could do at any time. But if a man who had been making his best efforts in jumping, cleared only a height of four feet, and presently being told to jump over an eight feet wall, cleared the height with apparent ease, we should be disposed to regard the feat as savoring of the miraculous.

Now, Dr. Carpenter saw one of Mr. Braid's hypnotized subjects—a man so remarkable for the poverty of his physical development that he had not, for many years, ventured to lift up a weight of twenty pounds in his ordinary state—take up a quarter of a hundred weight upon his little finger, and swing it round his head with the utmost apparent ease, on being told that it was as light as a feather. "On another occasion he lifted a half hundred weight on the last joint of his fore-finger as high as his knee." The personal character of the man placed him above all suspicion of deceit in the opinion of those who best knew him; and as Dr. Carpenter acutely remarks, "the impossibility of any trickery in such a case would be evident to the educated eye, since, if he had practiced such feats (which very few, even of the strongest men, could accomplish without practice), the effect would have made itself visible in his muscular development." "Consequently," he adds, "when the same individual afterwards declared himself unable, with the greatest effort, to lift a handkerchief from the table, after having been assured that he could not possibly move it, there was no reason for questioning the truth of his conviction, based as this was upon the same kind of suggestion as that by which he had been just before prompted to what seemed an otherwise impossible action."

The explanation of this and the preceding cases cannot be mistaken by physiologists, and is very important in its bearing on the phenomena of hypnotism generally, at once involving an interpretation of the whole series of phenomena, and suggesting other relations not as yet illustrated experimentally. It is well known that in our ordinary use of any muscles we employ but a small part of the muscle at any given moment. What the muscle is actually capable of is shown in convulsive contractions, in which far more force is put forth than the strongest effort of the will could call into play. We explain, then, the seeming increase of strength in any set of muscles during the hypnotic state as due to the concentration of the subject's will in an abnormal manner, or to an abnormal degree, on that set of muscles. In a similar way, the great increase of certain powers of perception may be explained as due to the concentration of the will upon the corresponding parts of the nervous system.

In like manner, the will may be directed so entirely to the operations necessary for the performances of difficult feats, that the hypnotized or somnambulistic subject may be able to accomplish what in his ordinary condition would be impossible or even utterly appalling to him. Thus sleep-walkers (whose condition precisely resembles that of the artificially hypnotized, except that the suggestions they experience come from contact with inanimate objects, instead of being aroused by the actions of another person) "can clamber walls and roofs, traverse narrow planks, step firmly along high parapets, and perform other feats which they would shrink from attempting in their waking state." This is simply, as Dr. Carpenter points out, because they are *not distracted* by the sense of danger which their vision would call up from concentrating their exclusive attention on the guidance afforded by their muscular sense."

But the most remarkable and suggestive of all the facts known respecting hypnotism is the influence which can by its means be brought to bear upon special parts or functions of the body. We know that imagination will hasten or retard certain processes commonly regarded as involuntary (indeed, the influence of imagination is itself in a great degree involuntary). We know further that in some cases imagination will do much more than this, as in the familiar cases of the disappearance of warts under the supposed influence of charms, the cure of scrofula at a touch, and hundreds of well-attested cases of so-called miraculous cures. But although the actual cases of the curative influence obtained over hypnotized patients may not be in reality more striking than some of these, yet they are more suggestive at any rate to ordinary minds, because they are known not to be the result of any charm or miraculous interference, but to be due to simply natural processes initiated by natural though unfamiliar means.

Take, for instance, such a case as the following, related by Dr. Carpenter (who has himself witnessed many remarkable cases of hypnotic cure): "A female relative of Mr. Braid's was the subject of a severe rheumatic fever, during the course of which the left eye became seriously implicated, so that after the inflammatory action had passed away, there was an opacity over more than one-half of the cornea, which not only prevented distinct vision, but occasioned an annoying disfigurement. Having placed herself under Mr. Braid's hypnotic treatment for the relief of violent pain in her arm and shoulder, she found, to the surprise alike of herself and Mr. Braid, that her sight began to improve very perceptibly. The operation was therefore continued daily; and in a very short time the cornea became so transparent that close inspection was required to discover any remains of the opacity." On this, Carpenter remarks that he has known other cases in which secretions that had been morbally suspended have been reinduced by this process; and is satisfied that, if applied with skill and discrimination, it would take rank as one of the most potent methods of treatment which the physician has at his command. He adds that "the channel of influence is obviously the system of nerves which regulates the secretions—nerves which, though not under direct subjection to the will, are peculiarly affected by emotional states."

I may remark, in passing, that nerves which are not ordinarily under the influence of the will, but whose office would be to direct muscular movements if only the will could influence them, may by persistent attention become obedient to the will. When I was last in New York, I met a gentleman who gave me a long and most interesting account of certain experiments which he had made on himself. The account was not forced on me, the reader must understand, but was elicited by questions suggested by one or two remarkable facts which he had casually

mentioned as falling within his experience. I had only his own word for much that he told me, and some may perhaps consider that there was very little truth in the narrative. I may pause here to make some remarks, by the way, on the traits of truthful and untruthful persons. I believe very slight powers of observation are necessary to detect want of veracity in any man, though absence of veracity in any particular story may not be easily detected or established. I am not one of those who believe every story they hear, and trust in every one they meet. But I have noticed one or two features by which the habitual teller of untruths may be detected very readily, as may also one who, without telling actual falsehoods, tries to heighten the effect of any story he may have to tell, by strengthening all the particulars. My experience in this respect is unlike Dickens's, who believed, and indeed found, that a man whom on first seeing he distrusted, and justly, could explain away the unfavorable impression. "My first impression," he says, "about such people, founded on face and manner alone, was invariably true; my mistake was in suffering them to come nearer to me and explain themselves away." I have found it otherwise, though, of course, Dickens was right about his own experience; the matter depends entirely on the idiosyncrasies of the observer. I have often been deceived by face and expression; never, to the best of my belief (and belief in this case is not mere opinion, but is based on results), by manner of speaking. One peculiarity I have never found wanting in habitually mendacious persons—a certain intonation which I cannot describe, but recognize in a moment, suggestive of the weighing of each sentence as it is being uttered, as though to consider how it would tell. Another is a peculiarity of manner, but it only shows itself during speech; it is a sort of watchfulness often disguised under a careless tone, but perfectly recognizable however disguised. Now, the gentleman who gave me the experience I am about to relate conveyed to my mind, by every intonation of his voice and every peculiarity and change of manner, the idea of truthfulness. I cannot convey to others the impression thus conveyed to myself; nor do I expect that others will share my own confidence; I simply state the case as I know it, and as far as I know it. It will, however, be seen that a part of the evidence was confirmed on the spot.

The conversation turned on the curability of consumption. My informant, whom I will henceforth call A., said that, though he could not assert from experience that consumption was curable, he believed that in many cases where the tendency to consumption is inherited, and the consumptive constitution indicated so manifestly that under ordinary conditions the person would before long be hopelessly consumptive, an entire change may be made in the condition of the body, and the person become strong and healthy. He said: "I belong myself to a family many of whose members have died of consumption. My father and mother both died of it, and all my brothers and sisters save one brother; yet I do not look consumptive, do I?" And certainly he did not. He then took from a pocket-book a portrait of his brother, showing a young man manifestly in very bad health, looking worn, weary, and emaciated. From the same pocket-book A. then took another portrait asking if I recognized it. I saw here again a worn and emaciated face and figure. The picture was utterly unlike the hearty, well-built man before me, yet it manifestly represented no other. If I had been at all doubtful, my doubts would have been removed by certain peculiarities to which A. called my attention. I asked how the change in his health had been brought about. He told me a very remarkable story of his treatment of himself, part of which I omit because I am satisfied he was mistaken in attributing to that portion of his self-

treatment any part of the good result which he had obtained, and that if many consumptive patients adopted the remedy, a large proportion, if not all, would inevitably succumb very quickly. The other portion of his account is all that concerns us here, being all that illustrates our present subject. He said: "I determined to exercise every muscle of my body; I set myself in front of a mirror and concentrated my attention and all the power of my will on the muscle or set of muscles I proposed to bring into action. Then I exercised those muscles in every way I could think of, continuing the process till I had used in succession every muscle over which the will has control. While carrying out this system, I noticed that gradually the will acquired power over muscles which before I had been quite unable to move. I may say, indeed, that every set of muscles recognized by anatomists, except those belonging to internal organs, gradually came under the control of my will." Here I interrupted, asking (not by any means as doubting his veracity, for I did not): "Can you do what Dundreary said he thought some fellow might be able to do—can you waggle your left ear?" "Why, certainly," he replied; and turning the left side of his head towards me, he moved his left ear about; not, it is true, waggling it, but drawing it up and down in a singular way, which was, he said, the only exercise he ever gave it. He said, on this, that there are many other muscles over which the will has ordinarily no control, but may be made to obtain control; and forthwith, drawing the cloth of his trousers rather tight round the thigh (so that the movement he was about to show might be discernible) he made in succession the three muscles of the front and inner side of the thigh rise about half an inch along some nine or ten inches of their length. Now, though these muscles are among those which are governed by the will, for they are used in a variety of movements, yet not one in ten thousand, perhaps in a million, can move them in the way described.

How far A.'s system of exciting the muscles individually as well as in groups may have operated in improving his health, as he supposed, I am not now inquiring. What I wish specially to notice is the influence which the will may be made to obtain over muscles ordinarily beyond its control. It may be that under the exceptional influence of the imagination, in the hypnotic condition, the will obtains a similar control for a while over even those parts of the nervous system which appertain to the so-called involuntary processes. In other words, the case I have cited may be regarded as occupying a sort of middle position between ordinary cases of muscular action and those perplexing cases in which the hypnotic subject seems able to influence pulsation, circulation, and processes of secretion in the various parts or organs of his body.

It must be noted, however, that the phenomena of hypnotism are due solely to the influence of the imagination. The quasi-scientific explanations which attributed them to magnetism, electricity, some subtle animal fluid, some occult force, and so forth, have been as completely negatived as the supernatural explanation. We have seen that painted wooden tractors were as effectual as the metal tractors of the earlier mesmerists; a small disc of card or wood is as effective as the disc of zinc and copper used by the electro-biologists; and now it appears that the mystical influence, or what was thought such, of the operator is no more essential to success than magnetic or electric apparatus.

Dr. Noble, of Manchester, made several experiments to determine this point. Some among them seem absolutely decisive.

Thus, a friend of Dr. Noble's had a female servant whom he had frequently thrown into the hypnotic state, trying a variety of experiments

many of which Dr. Noble had witnessed. Dr. Noble was at length told that his friend had succeeded in magnetizing her from another room and without her knowledge, with some other stories even more marvelous, circumstantially related by eye witnesses, "amongst others by the medical attendant of the family, a most respectable and intelligent friend" of Dr. Noble's own. As he remained unsatisfied, Dr. Noble was invited to come and judge for himself, proposing whatever test he pleased. "Now had we visited the house," he says, "we should have felt dissatisfied with any result," knowing "that the presence of a visitor or the occurrence of anything unusual was sure to excite expectation of some mesmeric process." "We therefore proposed," he proceeds, "that the experiment should be carried on at our own residence; and it was made under the following circumstances: The gentleman early one evening wrote a note as if on business, directing it to ourselves. He thereupon summoned the female servant (the mesmeric subject), requesting her to convey the note to its destination, and to wait for an answer. The gentleman himself, in her hearing, ordered a cab, stating that if anyone called he was going to a place named, but was expected to return by a certain hour. Whilst the female servent was dressing for her errand, the master placed himself in the vehicle and rapidly arrived at our dwelling. In about ten minutes after the note arrived, the gentleman, in the meantime, being secreted in an adjoining apartment, we requested the young woman who had been shown into our study to take a seat whilst we wrote the answer; at the same time placing the chair with its back to the door leading into the next room, which was left ajar. It had been agreed that after the admission of the girl into the place where we were, the magnetizer, approaching the door in silence on the other side, should commence operations. There, then, was the patient or "subject" placed within two feet of her magnetizer, a door only intervening, and that but partially closed; but she, all the while, perfectly free from all idea of what was going on. We were careful to avoid any unnecessary conversation with the girl, or even to look towards her, lest we should raise some suspicion in her own mind. We wrote our letter (as if in answer) for nearly a quarter of an hour, once or twice only making an indifferent remark, and on leaving the room for a light to seal the supposed letter, we beckoned the operator away. No effect whatever had been produced, although we had been told that two or three minutes were sufficient, even when mesmerizing from the drawing-room, through walls and apartments, into the kitchen. In our own experiment the intervening distance has been very much less, and only one solid substance intervened, and that not completely; but here we suspect was the difference—*the "subject" was unconscious of the magnetism, and expected nothing.*"

In another case Dr. Noble tried the converse experiment with equally convincing results. Being in company one evening with a young lady said to be of high mesmeric susceptibility, he requested and received permission to test this quality in her. In one of the usual ways he "magnetized" her, and having so far satisfied himself, he "demagnetized" her. He next proceeded to "hypnotize" her, adopting Mr. Braid's method of directing the stare at a fixed point. "The result varied in no respect from that which had taken place in the foregoing experiment; the duration of the process was the same, and its intensity of effect neither greater nor less." "Dehypnotization" again restored the young lady to herself. "And now," says Dr. Noble, "we requested our patient to rest quietly at the fire-place, to think of just what she liked, and to look where she pleased, excepting at ourselves, who retreated behind her chair, saying that a new mode was about to be

tried, and that her turning round would disturb the process. We very composedly took up a volume which lay upon a table, and amused ourselves with it for about five minutes, when on raising our eyes, we could see by the excited features of other members of the party that the young lady was once more *magnetized*. We were informed by those who had attentively watched her during the progress of our little experiment, that all had been in every respect just as before. The lady herself, before she was undeceived, expressed a distinct consciousness of having *felt our unseen passes streaming down the neck*."

In a similar way, Mr. Bertrand, who was the first (Dr. Carpenter tells us) to undertake a really scientific investigation of the phenomena of mesmerism, proved that the supposed effect of a magnetized letter from him to a female somnambule was entirely the work of her own lively imagination. He magnetized a letter first, which on receipt was placed at his suggestion upon the epigastrium of the patient, who was thrown into the magnetic sleep with all the customary phenomena. He then wrote another letter, which he did not magnetize, and again the same effect was produced. Lastly he set about an experiment which should determine the real state of the case. "I asked one of my friends," he says, "to write a few lines in my place, and to strive to imitate my writing, so that those who should read the letter should mistake it for mine (I knew he could do so). He did this; our stratagem succeeded, and the sleep was produced just as it would have been by one of my own letters.

It is hardly necessary to say, perhaps, that none of the phenomena of hypnotism require, as indeed none of them, rightly understood, suggest, the action of any such occult forces as spiritualists believe in. On the other hand, I believe that many of the phenomena recorded by spiritualists as having occured under their actual observation are very readily to be explained as phenomena of hypnotism. Of course I would not for a moment deny that in the great majority of cases much grosser forms of deception are employed. But in others, and especially in those where the concentration of the attention for some time is a necessary preliminary to the exhibition of the phenomena (which suitable "subjects" only are privileged to see), I consider the resulting self-deception as hypnotic.

We may regard the phenomena of hypnotism in two aspects—first and chiefly as illustrating the influence of imagination on the functions of the body; secondly, as showing under what conditions the imagination may be most readily brought to bear in producing such influence. These phenomena deserve far closer and at the same time far wider attention than they have yet received. Doubt has been thrown upon them because they have been associated with false theories, and in many cases with fraud and delusion. But, rightly viewed, they are at once instructive and valuable. On the one hand they throw light on some of the most interesting problems of mental physiology; on the other they promise to afford valuable means of curing certain ailments, and of influencing in useful ways certain powers and functions of the body. All that is necessary, it should seem, to give hypnotic researches their full value, is that all association of those purely mental phenomena with charlatanry and fraud should be abruptly and definitely broken off. Those who make practical application of the phenomena of hypnotism should not only divest their own minds of all idea that some occult and as it were extra-natural force is at work, but should encourage no belief in such force in those on whom the hypnotic method is employed. Their influence on the patient will not be lessened, I believe, by the fullest knowledge on the patient's part that all which is to happen to him is purely natural—that, in fact, advantage is simply to be taken of an

observed property of the imagination to obtain an influence not otherwise attainable over the body as a whole (as when the so-called magnetic sleep is to be produced), or over special parts of the body. Whether advantage might not be taken of other than the curative influences of hypnotism is a question which will probably have occurred to some who may have followed the curious accounts given in the preceding pages. If special powers may be obtained, even for a short time, by the hypnotized subject, these powers might be systematically used for other purposes than mere experiment. If, again, the repetition of hypnotic curative processes eventually leads to a complete and lasting change in the condition of certain parts or organs of the body, the repetition of the exercise of special powers during the hypnotic state may after a while lead to the definite acquisition of such powers As it now appears that the hypnotic control may be obtained without any effort on the part of the operator, the effort formerly supposed to be required being purely imaginary and the hypnotic state being in fact readily attainable without any operation whatever, we seem to recognize possibilities which, duly developed, might be found of extreme value to the human race. In fine, it would seem that man possesses a power which has hitherto lain almost entirely dormant, by which, under the influence of properly guided imagination, the will can be so concentrated on special actions that feats of strength, dexterity, artistic (and even perhaps scientific) skill may be accomplished by persons who, in the ordinary state, are quite incapable of such achievements.

III.

BODILY ILLNESS AS A MENTAL STIMULANT

During special states of disease the mind sometimes develops faculties such as it does not possess when the body is in full health. Some of the abnormal qualities thus exhibited by the mind seem strikingly suggestive of the possible acquisition by the human race of similar powers under ordinary conditions. For this reason, though we fear there is no likelihood at present of any practical application of the knowledge we may obtain on this subject, it seems to me that there is considerable interest in examining the evidence afforded by the strange powers which the mind occasionally shows during diseases of the body, and especially during such diseases as are said, in unscientific but expressive language, to lower the tone of the nervous system.

We may begin by citing a case which seems exceedingly significant. Miss H. Martineau relates that a congenital idiot, who had lost his mother when he was less than two years old, when dying, "suddenly turned his head, looked bright and sensible, and exclaimed in a tone never heard from him before, 'Oh, my mother! how beautiful!' and sank down again—dead." Dr. Carpenter cites this as a case of abnormal memory, illustrating his thesis that the basis of recollection "may be laid at a very early period of life." But the story seems to contain a deeper meaning. The poor idiot not only recalled a long-past time, a face that he had not seen for years, except in dreams, but he gained for a moment a degree of intelligence which he had not possessed when in health. The quality of his brain was such, it appears, that with the ordinary activity of the circulation, the ordinary vitality of the organ, mental action was uncertain and feeble; but when the circulation had all but ceased, when the nervous powers were all but prostrate, the feeble brain, though it may have become no stronger actually, became relatively stronger, in such sort that for the time specified, a mere moment before dissolution, the idiot became an intelligent being.

A somewhat similar case is on record in which an insane person, during that stage of typhus fever in

which sane persons are apt to become delirious, became perfectly sane and reasonable, his insanity returning with returning health. Persons of strongest mind in health are often delirious for a short time before death. Since, then, the idiot in the same stage of approaching dissolution may become intelligent, while the insane may become sane under the conditions which make the sane become delirious, we recognize a relationship between the mental and bodily states which might be of considerable use in the treatment of mental diseases. It may well be that conditions of the nervous system which are to be avoided by persons of normal mental qualities may be advantageously superinduced in the case of those of abnormally weak or abnormally violent mind. It is noteworthy that different conditions would seem to be necessary for the idiotic and for the insane, if the cases cited sufficed to afford basis for generalization. For the idiot of Miss Martineau's story became intelligent during the intense depression of the bodily powers immediately preceding dissolution, whereas the insane person became sane during that height of fever when delirium commonly makes its appearance.

Sir H. Holland mentions a case which shows that great bodily depression may affect a person of ordinary clear and powerful mind. "I descended on one and the same day," he says, "two very deep mines in the Hartz mountains, remaining some hours under ground in each. While in the second mine, and exhausted both from fatigue and inanition, I felt the utter impossibility of talking longer with the German Inspector who accompanied me. Every German word and phrase deserted my recollection; and it was not until I had taken food and wine, and been some time at rest, that I regained them again."

A change in the mental condition is sometimes a sign of approaching serious illness, and is felt to be so by the person experiencing it. An American writer, Mr. Butterworth, quotes the following description given by a near relative of his who was suffering from extreme nervous debility: "I am in constant fear of insanity," she said, "and I wish I could be moved to some retreat for the insane. I understand my condition perfectly; my reason does not seem to be impaired; but I can think of *two things at the same time*. This is an indication of mental unsoundness, and is a terror to me. I do not seem to have slept at all for the last six months. If I sleep it must be in a succession of vivid dreams that destroy all impression of somnolence. Since I have been in this condition I seem to have a very vivid impression of what happens to my children who are away from home, and I am often startled to hear that these impressions are correct. I seem to have also a certain power of anticipating what one is about to say, and to read the motives of others. I take no pleasure in this strange increase of mental power; it is all unnatural. I cannot live in this state long, and I often wish I were dead."

It must, however, be remembered that persons who are in a state of extreme nervous debility, not only possess at times abnormal mental qualities, but are also affected morally. As Huxley has well remarked of some stories bearing on spiritualism, they come from persons who can hardly be trusted even according to their own account of themselves. Mr. Butterworth's relation described a mental condition which, even if quite correctly pictured as she understood it, may yet be explained without believing that any very marvelous increase had taken place in her mental powers. Among the vivid impressions which she constantly had of what might be happening to her children away from home, it would have been strange if some had not been correct. The power of anticipating what others were about to say is one which many imagine they have, mistaking the occasional coincidence between their

guesses and what has been next said for indications of a power which, in reality, they do not possess. And so also with regard to the motives of others. Many are apt, especially when out of health, to guess at others' motives, sometimes rightly, but often very wrongly, yet always rightly in their own behalf, no matter what evidence may presently appear to the contrary.

The case cited by Mr. Butterworth affords evidence rather of the unhealthy condition of the patient's mind than of abnormal powers, except as regards the power of thinking of two things at the same time, which we may fairly assume was not ordinarily possessed by its relative. It is rather difficult to define such a power, however. Several persons have apparently possessed the power, showing it by doing two things at the same time which both appear to require thought, and even close attention. Julius Cæsar, for example, could write on one subject and dictate on another simultaneously. But in reality, even in cases such as these, the mind does not think of two things at once. It simply takes them in turn, doing enough with each, in a short time, a mere instant, perhaps, to give work to the pen or to the voice, as the case may be, for a longer time. When Cæsar was writing a sentence, he was not necessarily thinking of what he was writing. He had done the thinking part of the work before; and was free, while continuing the mere mechanical process of writing, to think of matter for dictation to his secretary. So also while he was speaking he was free to think of matter for writing. If, indeed, the thought for each sentence of either kind had occupied an appreciable time, there would have been interruptions of his writing, if not of his dictation (dictation is not commonly a continuous process under any circumstances, even when shorthand writers take down the words). But a practiced writer or speaker can in a moment form a sentence which shall occupy a minute in writing and several seconds in speaking.

I certainly do not myself claim the power of thinking of two things at once—nay, I believe that no one ever had or could have such a power; yet I find it perfectly easy, when lecturing, to arrange the plan for the next ten minutes' exposition of a scientific subject, and to adopt the words themselves for the next twenty seconds or so, while continuing to speak without the least interruption. I can also work out a calculation on the blackboard while continuing to speak of matters outside the subject of the calculation. It is more a matter of habit than an indication of any mental power, natural or acquired, to speak or write sentences, even of considerable length, after the mind has passed on to other matters. In a similar way some persons can write different words with the right and left hands, and this, too, while speaking of other matters. (I have seen this done by Professor Morse, the American naturalist, whose two hands added words to the diagrams he had drawn while his voice dealt with other parts of the drawing: to add to the wonder, too, he wrote the words indifferently from right to left or from left to right.) In reality the person who thus does two things at once is no more thinking of two things at once than a clock is, when the striking and the working machinery are both in action at the same time.*

* Since the above was written I have noticed a passage in Dr. Carpenter's *Mental Physiology*, p. 719, bearing on the matter I have been dealing with: "The following statement recently made to me by a gentleman of high intelligence, the editor of a most important provincial newspaper, would be almost incredible, if cases somewhat similar were not already familiar to us: 'I was formerly,' he said, 'a reporter in the House of Commons; and it several times happened to me that, having fallen asleep from sheer fatigue towards the end of a debate, I had found, on awaking after a short interval of entire unconsciousness, that I had continued to note down correctly the speaker's words.'

As an illustration of special mental power shown in health, by a person whose mental condition in illness we shall consider afterwards, Sir Walter Scott may be mentioned. The account given by his amanuensis has seemed surprising to many, unfamiliar with the nature of literary composition (at least after long practice), but is in reality such as anyone who writes much can quite readily understand, or might even have known must necessarily be correct. "His thoughts," says the secretary to whom Scott dictated his *Life of Napoleon Buonaparte*, "flowed easily and felicitously, without any difficulty to lay hold of them or to find appropriate language" (which, by the way, is more than all would say who had read Scott's *Life of Buonaparte*, and certainly more than can be said of his secretary, unless it really was a familiar experience with him to be unable to lay hold of his thoughts). "This was evident by the absence of all solicitude (*miseria cogitandi*) from his countenance. He sat in his chair, from which he rose now and then, took a volume from the bookcase, consulted it, and restored it to the shelf—all without intermission in the current of ideas, which continued to be delivered with no less readiness than if his mind had been wholly occupied with the words he was uttering. It soon became apparent to me, however, that he was carrying on two distinct trains of thought, one of which was already arranged and in the act of being spoken, while at the same time he was in advance, considering what was afterwards to be said. "This I discovered (he should rather have said, "this I was led to infer") "by his sometimes introducing a word which was wholly out of place—*entertained* instead of *denied*, for example—but which I presently found to belong to the next sentence, perhaps four or five lines further on, which he had been preparing at the very moment when he gave me the words of the one that preceded it." In the same way I have often unconsciously substituted one word for another in lecturing, the word used always belonging to a later sentence than the word intended to be used. I have noticed also this peculiarity, that when a substitution of this kind has been once made, an effort is required to avoid repeating the mistake, even if it be not repeated quite unconsciously, to the end of the discourse. In this way, for example, I once throughout an entire lecture used the word "heavens" for the word "screen" (the screen on which lantern pictures were shown).

'I believe,' he added, 'that this is not an uncommon experience among Parliamentary reporters.' The reading aloud with correct emphasis and intonation, or the performance of a piece of music, or (as in the case of Albert Smith) the recitation of a frequently-repeated composition, whilst the conscious mind in *entirely engrossed* in its own thoughts and feelings may be thus accounted for without the supposition that the mind is actively engaged in two different operations at the same moment, which would seem tantamount to saying that there are two egos in the same organism." An instance in my own experience seems even more remarkable than the reporter's work during sleep, for he had but to continue a mechanical process, whereas in my case there must have been thought. Late one evening at Cambridge I began a game of chess with a fellow-student (now a clergyman, and well-known in chess circles). I was tired after a long day's rowing, but continued the game to the best of my ability, until at a certain stage I fell asleep, or rather fell into a waking-dream. At any rate, all remembrance of what passed after that part of the game had entirely escaped me when I awoke or returned to consciousness about three in the morning. The chessboard was there, but the men were not as when the last conscious move was made. The opponent's king was checkmated. I supposed my opponent had set the men in this position either as a joke or in trying over some end game. But I was assured that the game had continued to the end, and that I had won, apparently playing as if fully conscious! Of course I cannot certify this of my own knowledge.

A similar peculiarity may be noticed with written errors. Thus, in my treatise on a scientific subject, in which the utmost care had been given to minute points of detail, I once wrote "seconds" for "minutes" throughout several pages — in fact, from the place where first the error was made, to the end of the chapter. (See the *first* edition of my *Transits of Venus*, pp. 131–136, noting as an additional peculiarity that the whole object of the chapter in which this mistake was made was to show how many minutes of difference existed between the occurrence of certain events.)

An even more curious instance of a mistake arising from doing one thing while thinking of another occurred to me fourteen years ago. I was correcting the proof-sheets of an astronomical treatise in which occurred these words: "Calling the mean distance of the earth 1, Saturn's mean distance is 9·539; again, calling the earth's period 1, Saturn's mean period is 29·457:—now what relation exists between these numbers 9·539 and 29·457 and their powers? The first is less than the second, but the square of the first is plainly greater than the second; we must therefore try higher powers," etc., etc. The passage was quite correct as it stood, and if the two processes by which I was correcting verbal errors and following the sense of the passage had been really continuous processes of thought, unquestionably the passage would have been left alone. If the passage had been erroneous, and had been simply left in that condition, the case would have been one only too familiar to those who have had occasion to correct proofs. But what I actually did was deliberately to make nonsense of the passage while improving the sound of the second sentence. I made it run, "the first is less than the second, but the square of the first is plainly greater than the square of the second," the absurdity of which statement a child would detect. If the first proof in its correct form, with the incorrect correction carefully written down in the margin, had not existed when, several months later, the error was pointed out in the *Quarterly Journal of Science*, I should have felt sure that I had written the words wrongly at the outset. For blunders such as this are common enough. But that I should deliberately have taken a correctly-worded sentence and altered it into utter absurdity I could not, but for the evidence, have believed to be possible. The case plainly shows that not only may two things be done at once when the mind, nevertheless, is thinking only of one, but that something may be done which suggests deliberate reflection when in reality the mind is elsewhere or not occupied at all. For in this case both the processes on which I was engaged were manifestly carried on without thought, one being purely mechanical, and the other, though requiring thought if properly attended to, being so imperfectly effected as to show that no thought was given to it.

To return to Sir Walter Scott. It is known but too well that during the later years of his life there came with bodily prostration a great but not constant failure of his mental powers. Some of the phenomena presented during this part of his career are strikingly illustrative of abnormal mental action occurring even at times when the mental power is on the whole much weakened. *The Bride of Lammermoor*, though not one of the best of Scott's novels, is certainly far above such works as *Count Robert of Paris*, *The Betrothed*, and *Castle Dangerous*. Its popularity may perhaps be attributed chiefly to the deep interest of the "ower true tale" on which it is founded: but some of the characters are painted with exceeding skill. Lucy herself is almost a nonentity, and Edgar is little more than a gloomy, unpleasant man, made interesting only by the troubles which fall on him. But Caleb Balderstone and Ailsie Gourlay stand out from the canvas as if alive; they are

as lifelike and natural, yet as thoroughly individualized as Edie Ochiltree and Meg Merrilies. The novel neither suggested when it first appeared, nor has been regarded even after the facts became known, as suggesting that Scott. when he wrote it, was in bad health, Yet it was produced under pressure of severe illness, and when Scott was at least in this sense unconscious, that nothing of what he said and did in connection with the work was remembered when he recovered. "The book," says James Ballantyne, "was not only written, but published, before Mr. Scott was able to rise from his bed; and he assured me that when it was first put into his hands in a complete shape, *he did not recollect one single incident, character, or conversation it contained!* He did not desire me to understand, nor did I understand, that his illness had erased from his memory the original incidents of the story, with which he had been acquainted from his boyhood. These remained rooted where they had ever been; or, to speak more explicitly, he remembered the general facts of the existence of the father and mother, of the son and daughter, of the rival lovers, of the compulsory marriage, and the attack made by the bride upon the hapless bridegroom, with the general catastrophe of the whole. *All these things he recollected*, just as he did before he took to his bed; *but he literally recollected nothing else*—not a single character woven by the romancer, not one of the many scenes and points of humor, not *anything with which he was himself connected*, as the writer of the work.

Later, when Scott was breaking down under severe and long-continued labor, and first felt the approach of the illness which ultimately ended in death, he experienced strange mental phenomena. In his diary for February 17, 1829, he notes that on the preceding day, at dinner, though in company with two or three old friends, he was haunted by "a sense of pre-existence," a confused idea that nothing that passed was said for the first time; that the same topics had been discussed, and that the same persons had expressed the same opinions before. "There was a vile sense of a want or reality in all that I did or said."

Dr. Reynolds related to Dr. Carpenter a case in which a Dissenting minister, who was in apparently sound health, was rendered apprehensive of brain-disease—though, as it seemed, without occasion—by lapse of memory similar to that experienced by Sir Walter Scott. He "went through an entire pulpit service on a certain Sunday morning with the most perfect consistency—his choice of hymns and lessons, and his *extempore* prayer being all related to the subject of his sermon. On the following Sunday morning he went through the introductory part of his service in precisely the same manner—giving out the same hymns, reading the same lessons, and directing the *extempore* prayer in the same channel. He then gave out the same text and preached the very same sermon as he had done on the previous Sunday. When he came down from the pulpit, it was found that he had not the smallest remembrance of having gone through precisely the same service on the previous Sunday; and when he was assured of it, he felt considerable uneasiness lest his lapse of memory should indicate some impending attack of illness. None such, however, supervened; and no *rationale* can be given of this curious occurrence, the subject of it not being liable to fits of 'absence of mind' and not having had his thoughts engrossed at the time by any other special pre-occupation." It is possible that the explanation here is the simple one of mere coincidence. Whether this explanation is available or not would depend entirely on the question whether the preacher's memory was ordinarily trustworthy or not, whether in fact he would remember the arrangements, prayers, sermon, etc., he had given on any occasion. These

matters, becoming, after long habit, almost automatic, it might very well happen that the person going through such duties would remember them no longer and no better than one who had been present when they were performed, and who had not paid special attention to them. That if he had thus unconsciously carried out his duties on one Sunday, he should (being to this degree forgetful) conduct them in precisely the same way on the next Sunday, would rather tend to show that his mental faculties were in excellent working order than the reverse. Wendell Holmes tells a story which effectively illustrates my meaning; and he tells it so pleasantly (as usual) that I shall quote it unaltered. "Sometimes, but rarely," he says, "one may be caught making the same speech twice over, and yet be held blameless. Thus a certain lecturer" (Holmes himself, doubtless), "after performing in an inland city, where dwells a *litteratrice* of note, was invited to meet her and others over the social tea cup. She pleasantly referred to his many wanderings in his new occupation. 'Yes,' he replied, 'I am like the huma, the bird that never lights, being all ways in the cars, as he is always on the wing.' Years elapsed. The lecturer visited the same place once more for the same purpose. Another socia-cup after the lecture, and a second meeting with the distinguished lady. 'You are constantly going from place to place,' she said. 'Yes,' he answered, 'I am like the huma,' and finished the sentence as before. What horror when it had flashed over him that he had made this fine speech, word for word, twice over! Yet it was not true, as the lady might perhaps have fairly inferred, that he had embellished his conversation with the huma daily during the whole interval of years. On the contrary, he had never once thought of the odious fowl until the recurrence of precisely the same circumstances brought up precisely the same idea." He was not in the slightest degree afraid of brain disease. On the contrary, he considered the circumstance indicative of good order in the mental mechanism. "He ought to have been proud," says Holmes, speaking for him, and meaning no doubt that he *was* proud, "of the accuracy of his mental adjustments. *Given certain factors, and a sound brain should always evolve the same fixed product with the certainty of Babbage's calculating machine.*"

Somewhat akin to the unconscious recurrence of mental processes after considerable intervals of time is the tendency to imitate the actions of others, as though sharing in their thoughts, and according to many, *because* mind acts upon mind. This tendency, though not always associated with disease, is usually a sign of bodily illness. Dr. Carpenter mentions the following singular case, but rather as illustrating generally the influence of suggestions derived from external sources in determining the current of thought, than as showing how prone the thoughts are to run in undesirable currents when the body is out of health: "During an epidemic of fever, in which an active delirium had been a common symptom, it was observed that many of the patients of one particular physician were possessed by a strong tendency to throw themselves out of the window, whilst no such tendency presented itself in unusual frequency in the practice of others. The author's informant, Dr. C., himself a distinguished professor in the university, explained the tendency of what had occurred within his own knowledge, he having been himself attacked by the fever, and having been under the care of this physician, his friend and colleague, Dr. A. Another of Dr. A.'s patients, whom we shall call Mr. B., seems to have been the first to make the attempt in question, and, impressed with the necessity of taking due precautions, Dr. A. then visited Dr. C., *in whose hearing* he gave directions to have the windows properly secured, as Mr. B. had attempted to throw himself out. Now, Dr. C. distinctly

remembers that, although he had not previously experienced any such desire, it came upon him with great urgency as soon as ever the idea was thus suggested to him, his mind being just in that state of incipient delirium which is marked by the temporary dominance of some one idea, and by the want of volitional power to withdraw the attention from it. And he deemed it probable that, as Dr. A. went on to Mr. D., Mr. E., etc., and gave similar directions, a like desire would be excited in the minds of all those who might happen to be in the same impressible condition." The case is not only interesting as showing how the mind in disease receives certain impressions more strongly than in health, and in a sense may thus be said to possess for the time an abnormal power, but it affords a useful hint to doctors and nurses, who do not always (the latter indeed scarcely ever) consider the necessity of extreme caution when speaking about their patients and in their presence. It is probable that a considerable proportion of the accidents, fatal and otherwise, which have befallen delirious patients might be traced to incautious remarks made in their hearing by foolish nurses or forgetful doctors.

In some cases doctors have had to excite a strong antagonistic feeling against tendencies of this kind. Thus, Zerffi relates that an English physician was once consulted by the mistress of a ladies' school, where many girls had become liable to fits of hysterics. He tried several remedies, but in vain. At last, justly regarding the epidemic as arising from the influence of imagination on the weaker girls (one hysterical girl having infected the others), he determined to exert a stronger antagonistic influence on the weak minds of his patients. He therefore remarked casually to the mistress of the school, in the hearing of the girls, that he had now tried all methods but one, which he would try, as a last resource, when next he called—"the application of a red-hot iron to the spine of the patients, so as to quiet their nervously-excited systems." "Strange to say," remarks Zerffi—meaning no doubt, 'it is hardly necessary to say that'—"the red-hot iron was never applied, for the hysterical attacks ceased as if by magic."

In another case mentioned by Zerffi, a revival mania in a large school near Cologne was similarly brought to an abrupt end. The Government sent an inspector. He found that the boys had visions of Christ, the Virgin, and departed saints. He threatened to close the school if these visions continued, and thus to exclude the students from all the prospects which their studies afforded them. "The effect was as magical as the red-hot iron remedy — the revivals ceased as if by magic."

The following singular cases are related in Zimmermann's *Solitude:* "A nun, in a very large convent in France, began to mew like a cat. At last all the nuns began to mew together every day at a certain time, and continued mewing for several hours together. This daily cat-concert continued, until the nuns were informed that a company of soldiers was placed by the police before the entrance to the convent, and that the soldiers were provided with rods with which they would whip the nuns until they promised not to mew any more." . . . "In the fifteenth century, a nun in a German convent fell to biting her companions. In the course of a short time all the nuns of this convent began biting each other. The news of this infatuation among the nuns soon spread, and excited the same elsewhere; the biting mania passing from convent to convent through a great part of Germany. It afterwards visited the nunneries of Holland, and even spread as far as Rome." No suggestion of bodily disease is made in either case. But any one who considers how utterly unnatural is the manner of life in monastic communities will not need the evidence derived from the spread of such preposterous habits to be as-

sured that in convents the perfectly sane mind in a perfectly healthy body must be the exception rather than the rule.

The dancing mania, which spread through a large part of Europe in the fourteenth and fifteenth centuries, although it eventually attacked persons who were seemingly in robust health, yet had its origin in disease. Dr. Hecker, who has given the most complete account we have of this strange mania, in his *Epidemics of the Middle Ages*, says that when the disease was completely developed the attack commenced with epileptic convulsions. "Those affected fell to the ground senseless, panting and laboring for breath. They foamed at the mouth, and suddenly springing up, began their dance amidst strange contortions. They formed circles hand in hand, and appearing to have lost all control over their senses, continued dancing, regardless of the bystanders, for hours together, in wild delirium, until at length they fell to the ground in a state of exhaustion. They then complained of extreme oppression, and groaned as if in the agonies of death, until they were swathed in clothes bound tightly round their waists; upon which they again recovered, and remained free from complaint until the next attack. . . . While dancing they neither saw nor heard, being insensible to external impressions through the senses; but they were haunted by visions, their fancies conjuring up spirits, whose names they shrieked out; and some of them afterwards asserted that they felt as if they had been immersed in a stream of blood, which obliged them to leap so high. Others during the paroxysm saw the heavens open, and the Savior enthroned with the Virgin Mary, according as the religious notions of the age were strangely and variously reflected in their imaginations." The epidemic attacked people of all stations, but especially those who led a sedentary life, such as shoemakers and tailors; yet even the most robust peasants finally yielded to it. They "abandoned their labors in the fields as if they were possessed by evil spirits, and those affected were seen assembling indiscriminately from time to time, at certain appointed places, and unless prevented by the lookers-on, continued to dance without intermission, until their very last breath was expended. Their fury and extravagance of demeanor so completely deprived them of their senses, that many of them dashed their brains out against the walls and corners of buildings, or rushed headlong in rapid rivers, where they found a watery grave. Roaring and foaming as they were, the bystanders could only succeed in restraining them by placing benches and chairs in their way, so that by the high leaps they were thus tempted to take, their strength might be exhausted. As soon as this was the case they fell, as it were, lifeless to the ground, and by very slow degrees recovered their strength. Many there were who even with all this exertion had not expended the violence of the tempest which raged within them; but awoke with newly revived powers, and again and again mixed with the crowd of dancers; until at length the violent excitement of their disordered nerves was allayed by the great involuntary exertion of their limbs, and the mental disorder was calmed by the exhaustion of the body. The cure effected by these stormy attacks was in many cases so perfect, that some patients returned to the factory or plough, as if nothing had happened. Others, on the contrary, paid the penalty of their folly by so total a loss of power that they could not regain their former health, even by the employment of the most strengthening remedies."

It may be doubted, perhaps, by some whether such instances as these illustrate so much the state to which the mind is reduced when the body is diseased, as the state to which the body is reduced when the mind is diseased, though, as we have seen, the dancing mania when fully developed followed always on bodily illness. In

the cases we now have to deal with, the diseased condition of the body was unmistakable.

Mrs. Hemans on her deathbed said that it was impossible for imagination to picture or pen to describe the delightful visions which passed before her mind. They made her waking hours more delightful than those passed in sleep. It is evident that these visions had their origin in the processes of change affecting the substance of the brain as the disease of the body progressed. But it does not follow that the substance of the brain was undergoing changes necessarily tending to its ultimate decay and dissolution. Quite possibly the changes were such as might occur under the influence of suitable medicinal or stimulant substances, and without any subsequent ill effects. Dr. Richardson, in an interesting article on ether-drinking and extra-alcoholic intoxication (*Gentleman's Magazine* for October), makes a remark which suggests that the medical men of our day look forward to the discovery of means for obtaining some such influence over the action of the brain. After describing the action of methylic and ethylic ethers in his own case, he says: "They who have felt this condition, who have lived as it were in another life, however transitorily, are easily led to declare with Davy that 'nothing exists but thoughts! the universe is composed of impressions, ideas, pleasures and pains!' I believe it is so, and that we might by scientific art, and there is such an art, learn to live altogether in a new sphere of impressions, ideas, pleasures, and pains." "But stay," he adds, as if he had said too much. "I am anticipating, unconsciously, something else that is in my mind. The rest is silence; I must return to the world in which we now live, and which all know."

Mr. Butterworth mentions the case of the Rev. William Tennent, of Freehold, New Jersey, as illustrative of strange mental faculties possessed during disease. Tennant was supposed to be far gone in consumption. At last, after a protracted illness, he seemingly died, and preparations were made for his funeral. Not only were his friends deceived, but he was deceived himself, for he thought he was dead, and that his spirit had entered Paradise. "His soul, as he thought, was borne aloft to celestial altitudes, and was enraptured by visions of God and all the hosts of Heaven. He seemed to dwell in an enchanted region of limitless light and inconceivable splendor. At last an angel came to him and told him he must go back. Darkness, like an overawing shadow, shut out the celestial glories; and, full of sudden horror, he uttered a deep groan. This dismal utterance was heard by those around him, and prevented him from being buried alive, after all the preparations had been made for the removal of the body."

We must not fall into the mistake of supposing, however, as many seem to do, that the visions seen under such conditions, or by ecstatics, really present truths of which the usual mental faculties could not become cognizant. We have heard such cases as the deathbed visions of Mrs. Hemans and the trance visions of Tennent urged as evidence in favor of special forms of doctrine. We have no thought of attacking these, but assuredly they derive no support from evidence of this sort. The dying Hindoo has visions which the Christian would certainly not regard as heaven born. The Mahomedan sees the plains of Paradise, peopled by the houris of his heaven, but we do not, on that account, accept the Koran as the sole guide to religious truth. The fact is, that the visions pictured by the mind during the disease of the body, or in the ecstatic condition, have their birth in the mind itself, and take their form from the teachings with which that mind has been imbued. They may, indeed, seem utterly unlike those we should expect from the known character of the visionary, just as the thoughts of a dying man may be, and

often are, very far removed from the objects which had occupied all his attention during the later years of his life. But if the history of the childhood and youth of an ecstatic could be fully known, or if (which is exceedingly unlikely) we could obtain a strictly truthful account of such matters from himself, we should find nearly every circumstance of his visions explained, or at least an explanation suggested. For, after all, much which would be necessary to exactly show the origin of all he saw would be lost, since the brain retains impressions of many things of which the conscious memory has entirely passed away.

The vivid picturing of forgotten events of life is a familiar experience of the opium-eater. Thus, De Quincy says: "The minutest incidents of childhood or forgotten scenes of later years were often revived. I could not be said to recollect them, for if I had been told of them when waking, I should not have been able to acknowledge them as part of my past experience. But placed as they were before me in dreams, like intuitions, and clothed in all their evanescent circumstances and accompanying feelings, I recognized them instantaneously." A similar return of long-forgotten scenes and incidents to the mind may be noticed, though not to the same degree, when wine has been taken in moderate quantity after a long fast.

The effects of hachisch are specially interesting in this connection, because, unless a very powerful dose has been taken, the hachischin does not wholly lose the power of introspection, so that he is able afterwards to recall what has passed through his mind when he was under the influence of the drug. Now, Moreau, in his interesting *Etudes Psychologiques* (*Du Hachich et d'Aliénation Mentale*), says that the first result of a dose sufficient to produce the *hachisch fantasia* is a feeling of intense happiness. "It is really *happiness* which is produced by the hachisch; and by this simply an enjoyment entirely moral, and by no means sensual, as we might be induced to suppose. This is surely a very curious circumstance, and some remarkable inferences might be drawn from it; this, for instance, among others—that every feeling of joy and gladness, even when the cause of it is exclusively moral—that those enjoyments which are least connected with material objects, the most spiritual, the most ideal, may be nothing else than sensations purely physical, developed in the interior of the system, as are those procured by hachisch. At least so far as relates to that of which we are internally conscious, there is no distinction between these two orders of sensations, in spite of the diversity in the causes to which they are due, for the hachisch-eater is happy, not like the gourmand or the famished man when satisfying his appetite, or the voluptuary in gratifying his amative desires, but like him who hears tidings which fill him with joy, like the miser counting his treasures, the gambler who is successful at play, or the ambitious man who is intoxicated with success."

My special object, however, in noting the effects of opium and hachisch, is rather to note how the mental processes or faculties observed during certain states of disease may be produced artificially, than to enter into the considerations discussed by Dr. Moreau. It is singular that while the Mohamedan order of Hachischin (or Assassins) bring about, by the use of their favorite drug, such visions as accompany the progress of certain forms of disease, the Hindoo devotees, called Yogi, are able to produce artificially the state of mind and body recognized in cataleptic patients. The less advanced Yogi can only enter the state of abstraction called reverie, but the higher orders can simulate absolute inanition, the heart apparently ceasing to beat, the lungs to act and the nerves to convey impressions to the brain, even though the body be subjected to processes which would cause extreme torture under ordinary

conditions. "When in this state," says Carpenter, "the Yogi are supposed to be completely possessed by Brahma, 'the supreme soul,' and to be incapable of sin in thought, word or deed." It has been supposed that this was the state into which those entered who in old times were resorted to as oracles. But it has happened that in certain stages of disease the power of assuming the death-like state has been possessed for a time. Thus, Colonel Townsend, who died in 1797, we read, had in his last sickness the extraordinary power of apparently dying and returning to life again at will. "I found his pulse sink gradually," says Dr. Cheyne, who attended him, "so that I could not feel it by the most exact or nice touch. Dr. Raymond could not detect the least motion of the heart, nor Dr. Skrine the least soil of the breath upon the bright mirror held to the mouth. We began to fear he was actually dead. He then began to breathe softly." Colonel Townsend repeated the experiment several times during his illness, and could always render himself insensible at will.

Lastly, I may mention a case, which, however, though illustrating in some degree the influence of bodily illness on the mind, shows still more strikingly how the mind may influence the body—that of Louise Lateau, the Belgian peasant. This girl had been prostrated by a long and exhausting illness, from which she recovered rapidly after receiving the sacrament. This circumstance made a strong impression on her mind. Her thoughts dwelt constantly on the circumstances attending the death of Christ. At length she noticed that on every Friday blood came from a spot on her left side. "In the course of a few months similar bleeding spots established themselves on the front and back of each hand, and on the upper surface of each foot, while a circle of small spots formed in the forehead, and the hæmorrhage from these recurred every Friday, sometimes to a considerable amount. About the same time, fits of ecstacy began to occur, commencing every Friday between eight and nine in the morning and ending about six in the evening, interrupting her in conversation, in prayer, or in manual occupations. This state," says Dr. Carpenter, "appears to have been intermediate between that of the biologized and that of the hypnotized subject; for whilst as unconscious as the latter of all sense impressions, she retained, like the former, a recollection of all that had passed through her mind during the ecstacy. She described herself as suddenly plunged into a vast flood of bright light, from which more or less distinct forms began to evolve themselves, and she then witnessed the several scenes of the Passion successively passing before her. She minutely described the cross and the vestments, the wounds, the crown of thorns about the head of the Savior, and gave various details regarding the persons about the cross, the disciples, holy women, Jews and Roman soldiers. And the progress of her vision might be traced by the succession of actions she performed at various stages of it. Most of these movements were expressive of her own emotions, whilst regularly, about three in the afternoon, she extended her limbs in the form of a cross. The fit terminated with a state of extreme physical prostration, the pulse being scarcely perceptible, the breathing slow and feeble and the whole surface bedewed with a cold perspiration. After this state had continued for about ten minutes, a return to the normal condition rapidly took place."

There seems no reason for supposing that there was any deceit on the part of Louise Lateau herself, though that she was self deceived no one can reasonably doubt. Of course many in Belgium, especially the more ignorant and superstitious (including large numbers of the clergy and of religious orders of men and women), believed that her ecstasies were miraculous, and no doubt she believed so herself. But none of the circum-

stances observed in her case, or related by her, were such as the physiologist would find any difficulty in accepting or explaining. Her visions were such as might have been expected in a person of her peculiar nervous organization, weakened as her body had been by long illness, and her mind affected by what she regarded as her miraculous recovery. As to the transudation of blood from the skin, Dr.Tuke, in his "Illustrations of the Influence of the Mind upon the Body in Health and Disease" (p.267), shows the phenomenon to be explicable naturally. It is a well-authenticated fact, that under strong emotional excitement blood escapes through the perspiratory ducts, apparently through the rupture of the walls of the capillary passages of the skin.

We see, then, in Louise Lateau's case, how the mind affected by disease may acquire faculties not possessed during health, and how in turn the mind thus affected may influence the body so strangely as to suggest to ignorant or foolish persons the operation of supernatural agencies.

The general conclusion to which we seem led by the observed peculiarities in the mental faculties during disease is, that the mind depends greatly on the state of the body for the co-ordination of its various powers. In health, these are related in what may be called the normal manner. Faculties capable of great development under other conditions exist in moderate degree only, while probably, either consciously or unconsciously, certain faculties are held in control by others. But during illness, faculties not ordinarily used suddenly or very rapidly acquire undue predominance, and controlling faculties usually effective are greatly weakened. Then for a while the mental capacity seems entirely changed. Powers supposed not to exist at all (for of mental faculties, as of certain other qualities, *de non existentibus et de non apparentibus eadem est ratio*) seem suddenly created, as if by a miracle. Faculties ordinarily so strong as to be considered characteristic seem suddenly destroyed, since they no longer produce any perceptible effect. Or, as Brown-Sequard says, summing up the results of a number of illustrative cases described in a course of lectures delivered in Boston: "It would seem that the mind is largely dependent on physical conditions for the exercise of its faculties, and that its strength and most remarkable powers, as well as its apparent weakness, are often more clearly shown and recognized by some inequality of ac tion in periods of disturbed and greatly impaired health."

IV.

DUAL CONSCIOUSNESS.

Rather more than two years ago, I considered, in the pages of "Science Byways," the theory originally propounded by Sir Henry Holland, but then recently advocated by Dr. Brown-Sequard, of New York, that we have two brains, each perfectly sufficient for the full performance of mental functions. I did not, for my own part, either advocate or oppose that theory, but simply considered the facts which had been urged in support of it, or which then occurred to me as bearing upon it, whether for or against. I showed, however, that some classes of phenomena which had been quoted in support of the theory seemed in reality opposed to it, when all circumstances were considered. For example, Brown-Sequard had referred to some of those well-known cases in which, during severe illness, a language forgotten in the patient's ordinary condition had been recalled, the recollection of the language enduring only while the illness lasted. I pointed to a case in which there had not been two mental conditions only, as indicated by the language of the patient, but three; the person in question having in the beginning of his illness spoken English only, in the middle of his illness French only, and on the day of his death Italian

only (the language of his childhood). The interpretation of that case, and of others of a similar kind, must, I remarked, be very different from that which Brown-Sequard assigned, perhaps correctly, "to cases of twofold mental life." A case of the last-named kind has recently been discussed in scientific circles, which seems to me to bear very forcibly on the question whether Holland's theory of a dual brain is correct. I propose briefly to describe and examine this case, and some others belonging to the same class, two of which were touched upon in my former essay, but slightly only, as forming but a small part of the evidence dealt with by Brown-Sequard, whose arguments I was then considering. I wish now to deal, not with the question of the duality of the brain, but with the more general question of dual or intermittent consciousness.

Among the cases dealt with by Brown-Sequard was that of a boy at Notting Hill, who had two mental lives. Neither life presented anything specially remarkable in itself. The boy was a well-mannered lad in his abnormal as well as in his normal condition,—or one might almost say (as will appear more clearly after other cases have been considered) that the *two* boys were quiet and well-behaved. But the two mental lives were entirely distinct. In his normal condition the boy remembered nothing which had happened in his abnormal condition; and *vice versa*, in his abnormal condition he remembered nothing which had happened in his normal condition. He changed from either condition to the other in the same manner. "The head was seen to fall suddenly, and his eyes closed, but he remained erect if standing at the time, or if sitting he remained in that position (if talking, he stopped for a while, and if moving, he stopped moving); and after a minute or two his head rose, he started up, opened his eyes, and was wide awake again." While the head was drooped he appeared as if either sleeping or falling asleep. He remained in the abnormal state for a period which varied between one hour and three hours; it appears that every day, or nearly every day, he fell once into his abnormal condition.

This case need not detain us long; but there are some points in it which deserve more attention than they seem to have received from Dr. Brown-Sequard. It is clear that if the normal and abnormal mental lives of this boy had been entirely distinct, then in the abnormal condition he would have been ignorant and—in those points in which manners depend on training—ill-mannered. He would have known only, in this condition, what he had learned in this condition; and as only about a tenth part of his life was passed in the abnormal condition, and presumably that portion of his life not usually selected as a suitable time for teaching him, the abnormal boy would of necessity have been much more backward in all things which the young are taught than the normal boy. As nothing of this kind was noted, it would appear probable that the boy's earlier years were common to both lives, and that his unconsciousness of his ordinary life during the abnormal condition extended only to those parts of his ordinary life which had passed since these seizures began. Unfortunately, Brown-Sequard's account does not mention when this had happened.

It does not appear that the dual brain theory is required so far as this case is concerned. The phenomena seem rather to suggest a peculiarity in the circulation of the brain corresponding in some degree to the condition probably prevailing during somnambulism or hypnotism, though with characteristic differences. It may at least be said that no more valid reason exists for regarding this boy's case as illustrating the distinctive duality of the brain than for so regarding some of the more remarkable cases of somnambulism;

for though these differ in certain respects from the boy's case, they resemble it in the circumstances on which Brown-Sequard's argument is founded. Speaking generally of hypnotism—that is, of somnambulism artificially produced—Dr. Carpenter says: "In hypnotism, as in ordinary somnambulism, no remembrance whatever is preserved, in the waking state, of anything that may have occurred during its continuance; although the previous train of thought may be taken up and continued uninterruptedly on the next occasion when hypnotism is induced." In these respects the phenomena of hypnotism precisely resemble those of dual consciousness as observed in the boy's case. In what follows, we observe features of divergence. Thus "when the mind is not excited to activity by the stimulus of external impressions, the hypnotized subject appears to be profoundly asleep; a state of complete torpor, in fact, being usually the first result of the process just described, and any subsequent manifestation of activity being procurable only by the prompting of the operator. The hypnotized subject, too, rarely opens his eyes; his bodily movements are usually slow; his mental operations require a considerable time for their performance; and there is altogether an appearance of heaviness about him which contrasts strongly with the comparatively wide-awake air of him who has not passed beyond the ordinary biological state."

It would not be easy to find an exact parallel to the case of the two-lived boy in any recorded instance of somnambulism. In fact, it is to be remembered that recorded instances of mental phenomena are all selected for the very reason that they are exceptional, so that it would be unreasonable to expect them closely to resemble each other. One case, however, may be cited, which in certain points resembles the case of Dr. Brown-Sequard's patient. It occurred within Dr. Carpenter's own experience. A young lady of highly nervous temperament suffered from a long and severe illness, characterized by all the most marked forms of hysterical disorder. In the course of this illness came a time when she had a succession of somnambulistic seizures. "The state of somnambulism usually supervened in this case in the waking state, instead of arising, as it more commonly does, out of the conditions of ordinary sleep. In this condition her ideas were at first entirely fixed upon one subject—the death of her only brother, which had occurred some years previously. To this brother she had been very strongly attached; she had nursed him in his last illness; and it was perhaps the return of the anniversary of his death, about the time when the somnambulism first occurred, that gave to her thoughts that particular direction. She talked constantly of him, retraced all the circumstances of his illness, and was unconscious of anything that was said to her which had not reference to this subject. . . . Although her eyes were open, she recognized no one in this state—not even her own sister, who, it should be mentioned, had not been at home at the time of her brother's last illness." (It will presently appear, however, that she was able to recognize those who were about her during these attacks, since she retained ill-feeling against one of them; moreover, the sentences which immediately follow suggest that the sense of sight was not dormant.) "It happened on one occasion that, when she passed into this condition, her sister, who was present, was wearing a locket containing some of their deceased brother's hair. As soon as she perceived this locket she made a violent snatch at it, and would not be satisfied until she had got it into her possession, when she began to talk to it in the most endearing and even extravagant terms. Her feelings were so strongly excited on this subject, that it was deemed prudent to check them; and as she was inaccessible to all entreaties for the relinquishment of the

locket, force was employed to obtain it from her. She was so determined, however, not to give it up, and was so angry at the gentle violence used, that it was found necessary to abandon the attempt, and having become calmer after a time, she passed off into ordinary sleep. Before going to sleep, however, she placed the locket under her pillow, remarking, 'Now I have hid it safely, and they shall not take it from me.' On awaking in the morning she had not the slightest consciousness of what had passed; but the impression of the excited feelings still remained, for she remarked to her sister, 'I cannot tell what it is that makes me feel so, but every time that S. comes near me I have a kind of shuddering sensation;' the individual named being a servant, whose constant attention to her had given rise to a feeling of strong attachment on the side of the invalid, but who had been the chief actor in the scene of the previous evening. This feeling wore off in the course of a day or two. A few days afterwards the somnambulism again returned; and the patient being upon her bed at the time, immediately began to search for the locket under her pillow." As it had been removed in the interval, "she was unable to find it, at which she expressed great disappointment, and continued searching for it, with the remark, 'It *must* be there—I put it there myself a few minutes ago, and no one can have taken it away.' In this state the presence of S. renewed her previous feelings of anger; and it was only by sending S. out of the room that she could be calmed and induced to sleep. The patient was the subject of many subsequent attacks, in every one of which the anger against S. revived, until the current of thought changed, no longer running exclusively upon what related to her brother, but becoming capable of direction by *suggestions* of various kinds presented to her mind, either in conversation, or, more directly, through the several organs of sense."

I have been particular in quoting the above account, because it appears to me to illustrate well, not only the relation between the phenomena of dual consciousness and somnambulism, but the dependence of either class of phenomena on the physical condition. If it should appear that dual consciousness is invariably associated with some disorder either of the nervous system or of the circulation, it would be impossible, or at least very difficult to maintain Brown-Sequard's explanation of the boy's case. For one can hardly imagine it possible that a disorder of the sort should be localized so far as the brain is concerned, while in other respects affecting the body generally. It so chances that the remarkable case recently dealt with by French men of science forms a sort of connecting link between the boy's case and the case just cited. It closely resembles the former in certain characteristic features, while it resembles the latter in the evidence which it affords of the influence of the physical condition on the phenomena of double consciousness. The original narrative by M. Azam is exceedingly prolix; but it has been skillfully condensed by Mr. H. J. Slack, in the pages of a quarterly journal of science. I follow his version in the main.

The subject of the disorder, Felida X., was born in Bordeaux, in 1843. Until the age of thirteen she differed in no respect from other girls. But about that time symptoms of hysterical disorder presented themselves, and although she was free from lung-disease, she was troubled with frequent spitting of blood. After this had continued about a year, she for the first time manifested the phenomena of double consciousness. Sharp pains attacked both temples, and in a few moments she became unconscious. This lasted ten minutes, after which she opened her eyes, and entered into what M. Azam calls her second state, in which she remained for an hour or two, after which the pains and unconsciousness came on again, and she

returned to her ordinary condition. At intervals of about five or six days such attacks were repeated; and her relations noticed that her character and conduct during her abnormal state were changed. Finding, also, that in her usual condition she remembered nothing which had passed when she was in the other state, they thought she was becoming idiotic; and presently called in M. Azam, who was connected with a lunatic asylum. Fortunately, he was not so enthusiastic a student of mental aberration as to recognize a case for the lunatic asylum in every instance of phenomenal action. He found Felida intelligent, but melancholy, morose and taciturn, very industrious, and with a strong will. She was very anxious about her bodily health. At this time the mental changes occurred more frequently than before. Nearly every day, as she sat with her work on her knees, a violent pain shot suddenly through her temples, her head dropped upon her breast, her arms fell by her side, and she passed into a sort of sleep, from which neither noises, pinches, nor pricks could awaken her. This condition lasted now only two or three minutes. "She woke up in quite another state, smiling gaily, speaking briskly, and trilling (*fredonnant*) over her work, which she recommenced at the point where she left it. She would get up, walk actively, and scarcely complained of any of the pains she had suffered from so severely a few minutes before. She busied herself about the house, paid calls, and behaved like a healthy young girl of her age. In this state she remembered perfectly all that had happened in her two conditions." (In this respect her case is distinct from both the former, and is quite exceptional. In fact, the inclusion of the consciousness of both conditions during the continuance of one condition only, renders her case not, strictly speaking, one of double consciousness, the two conditions not being perfectly distinct from each other). "In this second life, as in the other, her moral and intellectual faculties, though different, were incontestably sound. After a time (which, in 1858, lasted three or four hours), her gaiety disappeared, the torpor suddenly ensued, and in two or three minutes she opened her eyes and re-entered her ordinary life, resuming any work she was engaged in just where she left off. In this state she bemoaned her condition, and was quite unconscious of what had passed in the previous state. If asked to continue a ballad she had been singing, she knew nothing about it, and if she had received a visitor, she believed she had seen no one. The forgetfulness extended to everything which happened during her second state, and not to any ideas or information acquired before her illness." Thus her early life was held in remembrance during both her conditions, her consciousness in these two conditions being in this respect single; in her second or less usual condition she remembered also all the events of her life, including what had passed since these seizures began; and it was only in her more usual condition that a portion of her life was lost to her—that, namely, which had passed during her second condition. In 1858 a new phenomenon was noticed as occasionally occurring—she would sometimes wake from her second condition in a fit of terror, recognizing no one but her husband. The terror did not last long, however; and during sixteen years of her married life her husband only noticed this terror on thirty occasions.

A painful circumstance preceding her marriage somewhat forcibly exhibited the distinction between her two states of consciousness. Rigid in morality during her usual condition, she was shocked by the insults of a brutal neighbor, who told her of a confession made to M. Azam during her second condition, and accused her of shamming innocence. The attack —unfortunately but too well founded as far as facts were concerned—brought on violent convulsions, which

required medical attendance during two or three hours It is important to notice the difference thus indicated between the character of the personalities corresponding tc her two conditions. "Her moral faculties," says M. Azam, "were incontestably sound in her second life, though different," —by which, be it understood, he means simply that her sense of right and wrong was just during her second condition; not, of course, that her conduct was irreproachable. She was in this condition, as in the other, altogether responsible for her actions. But her power of self-control, or rather perhaps the relative power of her will as compared with tendencies to wrong-doing, was manifestly weaker during her second condition. In fact, in one condition she was oppressed and saddened by pain and anxiety, whereas in the other she was almost free from pain, gay, lighthearted and hopeful. Now I cannot altogether agree with Mr. Slack's remark, that if, during her second state, "she had committed a robbery or an assassination, no moral responsibility could have been assumed to rest upon her with any certainty, by any one acquainted with her history," for her moral faculties in her second condition being incontestably sound, she was clearly responsible for her actions while in that condition. But certainly, the question of punishment for such an offence would be not a little complicated by her two-fold personality. To a woman, in her ordinary condition, remembering nothing of the crime committed (on the supposition we are dealing with), in her abnormal condition, punishment for that crime would certainly seem unjust, seeing that her liability to enter into that condition had not in any degree depended on her own will. The drunkard who, waking in the morning with no recollection of the events of the past night, finds himself in jail for some crime committed during that time, although he may think the punishment he has to endure severe measure for a crime of which in his ordinary condition he is incapable, knows at least that he is responsible for placing himself under that influence which made the crime possible. Supposing even he had not had sufficient experience of his own character when under the influence of liquor, to have reason to fear he might be guilty of the offence, he yet perceives that to make intoxication under any circumstances an excuse for crime would be most dangerous to the community, and that he suffers punishment justly. But the case of dual consciousness is altogether different, and certainly where responsibility exists under both conditions, while yet impulse and the restraining power of will are differently related in one and the other condition, the problem of satisfying justice is a most perplexing one. Here are in effect two different persons residing in one body, and it is impossible to punish one without punishing the other also. Supposing justice waited until the abnormal condition was resumed, then the offender would probably recognize the justice of punishment; but if the effects of the punishment continued until the usual condition returned, a person would suffer who was conscious of no crime. If the offence were murder, and if capital punishment were inflicted, the ordinary individuality, innocent entirely of murder, would be extinguished along with the first, a manifest injustice. As Huxley says of a similar case, "the problem of responsibility is here as complicated as that of a prince-bishop, who swore as a prince and not as a bishop. 'But, your highness, if the prince is damned, what will become of the bishop,' said the peasant." *

* Should any doubt whether these conditions of dual existence are a reality (a doubt, however, which the next case dealt with in the text should remove), we would remind them that a similar difficulty unmistakably existed in the case of Eng and Chang, the Siamese twins. It would have been almost impossible to inflict any punishment on one by which the other would not have suffered, and

It does not appear to me that there is in the case of Felida X. any valid reason for regarding the theory of two brains as the only available ex planation. It is a noteworthy circumstance that the pains preceding each change of condition affected both sides of the head. Some modification of the circulation seems suggested as the true explanation of the changes in condition, though the precise nature of such modification, or how it may have been brought about, would probably be very difficult to determine. The state of health, however, on which the attacks depended seems to have affected the whole body of the patient, and the case presents no features suggesting any lateral localization of the cerebral changes.

On the other hand, the case of Sergeant F. (a few of the circumstances of which were mentioned in my essay entitled "Have we two Brains?") seems to corresespond with Dr. Holland's theory, though that theory is far from explaining all the circumstances. The man was wounded by a bullet which fractured his *left* parietal bone, and his *right* arm and leg were almost immediately paralyzed. When he recovered censciousness three weeks later, the *right* side of the body was completely paralyzed, and remained so for a year. These circumstances indicate that the cause of the mischief still existing lay in the shock which the left side of the brain received when the man was wounded. The right side may have learned (as it were) to exercise the functions formerly belonging to the left side, and thus the paralysis affecting the right side until this had happened may have passed away. These points are discussed in the essay above named, however, and need not here detain us. Others which were not then dealt with may now be noted with advantage. We would specially note some which render it doubtful whether in the abnormal condition the man's brain acts at all, whether in fact his condition, so far as consciousness is concerned, is not similar to that of a frog deprived of its brain in a certain well-known experiment. (This appears to be the opinion to which Professor Huxley inclines, though, with proper scientific caution, he seems disposed to suspend his judgment.) The facts are very singular, whatever the explanation may be.

In the normal condition, the man is what he was before he was wounded —an intelligent, kindly fellow, per forming satisfactorily the duties of a hospital attendant. The abnormal state is ushered in by pains in the forehead, as if caused by the constriction of a band of iron. In this state the eyes are open and the pupils dilated. (The reader will remember Charles Reade's description of David Dodd's eyes, "like those of a seal.") The eyeballs work incessantly and the jaws maintain a chewing motion. If the man is *en pays de connaissance*, he walks about as usual; but in a new place, or if obstacles are set in his way, he stumbles, feels about with his hands, and so finds his way. He offers no resistance to any forces which may act upon him, and shows no signs of pain if pins are thrust into his body by kindly experimenters. No noise affects him. He eats and drinks apparently without tasting or smelling his food, accepting assafœtida or vinegar as readily as the finest claret. He is sensible to light only under certain conditions. But the sense of touch is strangely exalted (in all respects apparently except as to sensations of pain or pleasure), taking, in fact, the place of all the other senses. I say the sense of touch, but it is not clear whether there is any real sensation at all. The man appears in the abnormal condition to be a mere machine. This is strikingly exemplified in the following case, which I translate directly from Dr. Mesnet's account: "He was walking in the gar den, under a group of trees, and his

capital punishment inflicted on one would have involved the death of the other.

stick, which he had dropped a few minutes before, was placed in his hands. He feels it, moves his hand several times along the bent handle of the stick, becomes watchful, seems to listen, suddenly he calls out, 'Henry!' then, 'There they are! there are at least a score of them! Join us two; we shall manage it.' And then, putting his hand behind his back, as if to take a cartridge, he goes through the movement of loading his weapon, lays himself flat on the grass, his head concealed by a tree, in the posture of a sharpshooter, and with shouldered weapon follows all the movements of the enemy, whom he fancies he sees at a short distance." This, however, is an assumption; the man cannot in this state *fancy* he sees, unless he has at least a recollection of the sensation of sight, and this would imply cerebral activity. Huxley, more cautious, says justly that the question arises "whether the series of actions constituting this singular pantomime was accompanied by the ordinary states of consciousness or not? Did the man dream that he was skirmishing? or was he in the condition of one of Vaucanson's automata—a mechanism worked by molecular changes in his nervous system? The analogy of the frog shows that the latter assumption is perfectly justifiable."

The pantomimic actions just related corresponded to what probably happened a few moments before the man was wounded; but this human automaton (so to call him, without theorizing as to his actual condition) goes through other performances. He has a good voice, and was at one time a singer in a *café*. "In one of his abnormal states he was observed to begin humming a tune. He then went to his room, dressed himself carefully, and took up some parts of a periodical novel which lay on his bed, as if he were trying to find something. Dr. Mesnet, suspecting that he was seeking his music, made up one of these into a roll and put it into his hand. He appeared satisfied, took up his cane and went downstairs to the door. Here Dr. Mesnet turned him round, and he walked quite contentedly in the opposise direction, toward the room of the *concierge* The light of the sun shining through a window now happened to fall upon him, and seemed to suggest the footlights of the stage on which he was accustomed to make his appearance. He stopped, opened his roll of imaginary music, put himself into the attitude of a singer, and sung, with perfect execution, three songs, one after the other, after which he wiped his face with his handkerchief and drank, without a grimace, a tumbler of strong vinegar and water which was put into his hand."

But the most remarkable part of the whole story is that which follows: "Sitting at a table in one of his abnormal states, Sergeant F. took up a pen, felt for paper and ink, and began to write a letter to his general, in which he recommended himself for a medal on account of his good conduct and courage." (Rather a strange thing, by the way, for a mere automaton to do.) "It occurred to Dr. Mesnet to ascertain experimentally how far vision was concerned in this act of writing. He therefore interposed a screen between the man's eyes and his hands; under these circumstances, F. went on writing for a short time, but the words became illegible, and he finally stopped, without manifesting any discontent. On the withdrawal of the screen, he began to write again where he had left off. The substitution of water for ink in the inkstand had a similar result. He stopped, looked at his pen, wiped it on his coat, dipped it in the water and began again, with a similar result. On another occasion, he began to write upon the topmost of ten superimposed sheets of paper. After he had written a line or two, this sheet was suddenly drawn away. There was a slight expression of surprise, but he continued his letter on the second sheet exactly as if it had been the first. This operation was repeated five times, so that the fifth

sheet contained nothing but the writer's signature at the bottom of the page. Nevertheless, when the signature was finished, his eyes turned to the top of the blank sheet and he went through the form of reading what he had written—a movement of the lips accompanying each word; moreover, with his pen, he put in such corrections as were needed, in that part of the blank page which corresponded with the position of the words which required correction in the sheets which had been taken away. If the five sheets had been transparent, therefore, they would, when superposed, have formed a properly-written and corrected letter. Immediately after he had written his letter, F. got up, walked down to the garden, made himself a cigarette, lighted and smoked it. He was about to prepare another, but sought in vain for his tobacco-pouch, which had been purposely taken away. The pouch was now thrust before his eyes and put under his nose, but he neither saw nor smelled it; when, however, it was placed in his hand, he at once seized it, made a fresh cigarette, and ignited a match to light the latter. The match was blown out and another lighted match placed before his eyes, but he made no attempt to take it; and if his cigarette was lighted for him, he made no attempt to smoke. All this time his eyes were vacant, and neither winked nor exhibited any contraction of the pupil."

These and other similar experiments are explained by Dr. Mesnet (and Professor Huxley appears to agree with him) by the theory that F. "sees some things and not others; that the sense of sight is accessible to all things which are brought into relation with him by the sense of touch, and, on the contrary, insensible to all things which lie outside this relation." It seems to me that the evidence scarcely supports this conclusion. In every case where F. appears to see, it is quite possible that in reality he is guided entirely by the sense of touch. All the circumstances accord much better with this explanation than with the theory that the sense of sight was in any way affected. Thus the sunlight shining through the window must have affected the sense of touch and in a manner similar to what F had experienced when before the footlights of the stage, where he was accustomed to appear as a singer. In this respect there was a much closer resemblance between the effect of sunlight and that of the light from footlights, than in the circumstances under which both sources of light affect the sense of sight. For in one case the light came from above, in the other from below; the heat would in neither case be sensibly localized. Again, when a screen was interposed between his eyes and the paper on which he was writing, he probably became conscious of its presence in the same way that a blind man is conscious of the presence of objects near him, even (in some cases) of objects quite remote, by some subtle effects discernible by the sense of touch excited to abnormal relative activity in the absence of impressions derived from the sense of sight. It is true that one might have expected him to continue writing legibly, notwithstanding the interposed screen; but the consciousness of the existence of what in his normal condition would effectually have prevented his writing legibly, would be sufficient to explain his failure. If, while in full possession of all our senses, the expectation of failure quite commonly causes failure, how much more likely would this be to happen to a man in F.'s unfortunate abnormal condition. The sense of touch again would suffice to indicate the presence of water instead of ink in his pen when he was writing. I question whether the difference might not be recognized by any person of sensitive touch after a little practice; but certainly a blind man, whose sense of touch was abnormally developed, would recognize the difference, as we know from experiments which have indicated even greater delicacy of perception than would be required

for this purpose. The experiment with superposed sheets of paper is more remarkable than any of the others, but certainly does not suggest that light makes any impression upon Sergeant F. It proves, in fact, so far as any experiment could prove such a point, that the sense of touch alone regulates the man's movements. Unconscious of any change (because, after the momentary surprise produced by the withdrawal of the paper, he still found he had paper to write on), he continued writing. He certainly did not in this case, as Dr Mesnet suggests, see all things which are brought into relation with him by the sense of touch; for if he had, he would not have continued to write when he found the words already written no longer discernible.

On the whole, it appears reasonable to conclude, as Professor Huxley does, that though F. may be conscious in his abnormal state, he may also be a mere automaton for the time being. The only circumstance which seems to oppose itself very markedly to the latter view is the letter-writing. Everything else that this man did was what he had already done prior to the accident. If it could be shown that the letters written in his abnormal state were transcripts, not merely *verbatim et literatim*, but exact in every point, of some which he had written before he was wounded, then a strong case would be made out for the automaton theory. Certainly, few instances have come under the experience of scientific men where a human being has so closely resembled a mere machine as this man appears to do in his abnormal condition.

The moral nature of F. in his abnormal condition is for this reason a matter of less interest than it would be, did he show more of the semblance of conscious humanity. Still it is worthy of notice, that, whereas in his normal condition he is a perfectly honest man, in his abnormal state "he is an inveterate thief, stealing and hiding away whatever he can lay his hands on with much dexterity, and with an absolutely absurd indifference as to whether the property is his own or not."

It will be observed that the cases of dual consciousness thus far considered, though alike in some respects, present characteristic divergences. In that of the boy at Norwood, the two characters were very similar, so far as can be judged, and each life was distinct from the other. The next case was only introduced to illustrate the resemblance in certain respects between the phenomena of somnambulism and those of double or rather alternating consciousness. The woman Felida X. changed markedly in character when she passed from one state to the other. Her case was also distinguished from that of the boy by the circumstance that in one state she was conscious of what had passed in the other, but while in this other state was unconscious of what had passed in the former. Lastly, in Sergeant F.'s case we have to deal with the effect of an injury to the brain, and find a much greater difference between the two conditions than in the other cases. Not only does the man change in character, but it may justly be said that he is little more than an animal, even if he can be regarded as more than a mere automaton while in the abnormal condition. We find that a similar variety characterizes other stories of double consciousness. Not only are no two cases closely alike, but no case has been noted which has not been distinguished by some very marked feature from all others.

Thus, although in certain respects the case we have next to consider resembles very significantly the case of Sergeant F., it also has a special significance of its own, and may help us to interpret the general problem presented to us by the phenomena of dual consciousness. I abridge and in some respects simplify the account given by Dr. Carpenter in his interesting treatise on *Mental Physiology*. Comments of my own are distinguished from the abridged narra-

tive by being placed within brackets:

A young woman of robust constitution had narrowly escaped drowning. She was insensible for six hours, and continued unwell after being restored to animation. Ten days later she was seized with a fit of complete stupor, which lasted four hours; when she opened her eyes she seemed to recognize no one, and appeared to be utterly deprived of the senses of hearing, taste and smell, as well as of the power of speech. Sight and touch remained, but though movements were excited and controlled by these senses, they seemed to arouse no ideas in her mind. In fact, her mental faculties seemed entirely suspended. Her vision at short distances was quick, and the least touch startled her; but unless she was touched or an object were placed where she could not help seeing it, she took no notice of what was passing around her. [It does not appear to me certain that at this stage of her illness she *saw* in the ordinary sense of the word; the sense of touch may alone have been affected, as it certainly is affected to some degree by an object so placed that *it could not but be seen by a short-sighted person*. But it is clear that later the sense of sight was restored, supposing, which is not perhaps probable, that it was ever lost in the early stage.] She did not even know her own mother, who attended constantly upon her. Wherever she was placed she remained. Her appetite was good, but [like F.] she ate indifferently whatever she was fed with, and took nauseous medicines as readily as agreeable food. Her movements were solely of the automatic kind. Thus, she swallowed food put into her mouth, but made no effort to feed herself. Yet when her mother had conveyed the spoon [in the patient's hand] a few times to her mouth, the patient continued the operation. It was necessary, however, to repeat this lesson every time she was fed, showing the complete absence of memory. "The very limited nature of her faculties, and the automatic life she was leading, appear further evident from the following particulars. One of her first acts on recovering from the fit had been to busy herself in picking the bedclothes; and as soon as she was able to sit up and be dressed, she continued the habit by incessantly picking some portion of her dress. She seemed to want an occupation for her fingers, and accordingly part of an old straw bonnet was given to her, which she pulled into pieces with great minuteness; she was afterwards bountifully supplied with roses: she picked off the leaves, and then tore them up into the smallest particles imaginable. A few days subsequently, she began forming upon the table, out of those minute particles, rude figures of roses and other common garden flowers; she had never received any instructions in drawing. Roses not being so plentiful in London, waste paper and a pair of scissors were put into her hand, and for some time she found an occupation in cutting the paper into shreds; after a time these cuttings assumed rude shapes and figures, and more particularly the shapes used in patchwork. At length she was supplied with proper materials for patchwork, and after some initiatory instruction, she took to her needle and to this employment in good earnest. She now labored incessantly at patchwork from morning till night, and on Sunday and week-days, for she knew no difference of days; nor could she be made to comprehend the difference. She had no remembrance from day to day of what she had been doing on the previous day, and so every morning commenced *de novo*. Whatever she began that she continued to work at while daylight lasted; manifesting no uneasiness for anything to eat or drink, taking not the slightest heed of anything which was going on around her, but intent only on her patchwork." From this time she began to improve, learning like a child to register ideas. She presently

learned worsted-work, and showed delight in the harmony of colors and considerable taste in selecting between good and bad patterns. After a while she began to devise patterns of her own. But still she had no memory from day to day of what she had done, and unless the unfinished work of one day was set before her on the next, she would begin something new.

And now, for the first time, ideas derived from her life before her illness seemed to be awakened within her. When pictures of flowers, trees, and animals were shown her, she was pleased; but when she was shown a landscape in which there was a river or a troubled sea, she became violently agitated, and a fit of spasmodic rigidity and insensibility immediately followed. The mere sight of water in motion made her shudder. Again, from an early stage of her illness she had derived pleasure from the proximity of a young man to whom she had been attached. At a time when she did not remember from one hour to another what she was doing, she would anxiously await his evening visit, and be fretful if he failed to pay it. When, during her removal to the country, she lost sight of him, she became unhappy and suffered from frequent fits; on the other hand, when he remained constantly near her, she improved in health, and early associations were gradually awakened.

At length a day came when she uttered her first words in this her second life. She had learned to take heed of objects and persons around her; and on one occasion seeing her mother excessively agitated, she became excited herself, and suddenly, yet hesitatingly, exclaimed, "What's the matter?" After this she began to articulate a few words. For a time she called every object and person "this," then gave their right names to wild flowers (of which she had been passionately fond when a child), and this "at a time when she exhibited not the least recollection of the 'old familiar friends and places' of her childhood." The gradual expansion of her intellect was manifested chiefly at this time in signs of emotional excitement, frequently followed by attacks of spasmodic rigidity and insensibility.

It was through the emotions that the patient was restored to the consciousness of her former self. She became aware that her lover was paying attention to another woman, and the emotion of jealousy was so strongly excited, that she had a fit of insensibility which resembled her first attack in duration and severity. But it restored her to herself. "When the insensibility passed off, she was no longer spell-bound. The veil of oblivion was withdrawn; and, as if awakening from a sleep of twelve months' duration, she found herself surrounded by her grandfather, grandmother, and their familiar friends and acquaintances. She awoke in the possession of her natural faculties and former knowledge, but without the slightest remembrance of anything which had taken place in the year's interval, from the invasion of the first fit to the [then] present time. She spoke, but she heard not; she was still deaf, but being able to read and write as formerly, she was no longer cut off from communication with others. From this time she rapidly improved, but for some time continued deaf. She soon perfectly understood by the motion of her lips what her mother said; they conversed with facility and quickness together, but she did not understand the language of the lips of a stranger. She was completely unaware of the change in her lover's affections which had taken place in her state of second consciousness, and a painful explanation was necessary. This, however, she bore very well; and she has since recovered her previous bodily and mental health.

There is little in this interesting narrative to suggest that the duality of consciousness in this case was in any way dependent on the duality of the brain. During the patient's ab-

normal condition, the functions of the brain [proper] would seem to have been for a time in complete abeyance, and then to have been gradually restored. One can perceive no reason for supposing that the shock she had sustained would affect one side rather than the other side of the brain, nor why her recovery should restore one side to activity and cause the side which (on the dual brain hypothesis) had been active during her second condition to resume its original activity. The phenomena appear to suggest that in some way the molecular arrangement of the brain matter became modified during her second condition; and that when the original arrangement was restored all recognizable traces of impressions received while the abnormal arrangement lasted were obliterated. As Mr. Slack presents one form of this idea, "the grey matter of the brain may have its molecules arranged in patterns somewhat analogous to those of steel filings under the influence of a magnet, but in some way the direction of the forces—or vibrations—may be changed in them. The pattern will then be different." We know certainly that thought and sensation depend on material processes,—chemical reaction between the blood and the muscular tissues. Without the free circulation of blood in the brain, there can be neither clear thought nor ready sensation. With changes in the nature of the circulation come changes in the quality of thought and the nature of sensation, and with them the emotions are changed also. Such changes affect all of us to some degree. It may well be that such cases as we have been dealing with are simply instances of the exaggerated operation of causes with which we are all familiar; and it may also be that in the exaggeration itself of these causes of change lies the explanation of the characteristic peculiarity of cases of dual consciousness—the circumstances, namely, that either the two states of consciousness are absolutely distinct one from the other, or that in one state only are events remembered which happened in the other, no recollection whatever remaining in this latter state of what happened in the other, or lastly, that only faint impressions excited by some intense emotion experienced in one state remain in the other state.

It seems possible, also, that some cases of another kind may find their explanation in this direction, as, for instance, cases in which, through some strange sympathy, the brain of one person so responds to the thoughts of another, that for the time being the personality of the person thus influenced may be regarded as in effect changed into that of the person producing the influence. Thus, in one singular case cited by Dr. Carpenter, a lady was "metamorphosed into the worthy clergyman on whose ministry she attended, and with whom she was personally intimate. I shall never forget," he says, "the intensity of the lackadaisical tone in which she replied to the matrimonial counsels of the physician to whom he (she) had been led to give a long detail of his (her) hypochondriacal symptoms: 'A wife for a dying man, doctor.' No *intentional* simulation could have approached the exactness of the imitation alike in tone, manner, and language, which spontaneously proceeded from the idea with which the fair subject was possessed, that she herself experienced all the discomforts whose detail she had doubtless frequently heard from the real sufferer." The same lady, at Dr. Carpenter's request, mentally "ascended in a balloon and proceeded to the North Pole in search of Sir John Franklin, whom she found alive; and her description of his appearance and that of his companions was given with an inimitable expression of sorrow and pity."

It appears to us that very great interest attaches to the researches made by Prof. Barrett into cases of this kind, and that it is in this direction we are to look for the explanation of many mysterious phenomena formerly regarded as supernatural, but probably all admitting (at least all that

have been properly authenticated) of being interpreted so soon as the circumstances on which consciousness depends shall have been determined Thus the following account of experiments made at the village school in Westmeath seem especially suggestive: "Selecting some of the village children, and placing them in a quiet room, giving each some small object to look at steadily, he found one amongst the number who readily passed into a state of reverie. In that state the subject could be made to believe the most extravagant statements, such as that the table was a mountain, a chair a pony, a mark on the floor an insuperable obstacle. The girl thus mesmerized passed on the second occasion into a state of deeper sleep or trance, wherein no sensation whatever was experienced, unless accompanied by pressure on the eyebrows of the subject. When the pressure of the fingers was removed, the girl fell back in her chair utterly unconscious of all around, and had lost all control over her voluntary muscles. On reapplying the pressure, though her eyes remained closed, she sat up and answered questions readily, but the manner in which she answered them, her acts and expressions, were capable of wonderful diversity, by merely altering the place on the head where the pressure was applied. So sudden and marked were the changes produced by a movement of the fingers, that the operation seemed very like playing on some musical instrument. On a third occasion the subject, after passing through these, which have been termed the biological and phrenological states, became at length keenly and wonderfully sensitive to the voice and acts of the operator. It was impossible for the latter to call the girl by her name, however faintly and inaudibly to those around, without at once eliciting a prompt response. If the operator tasted, smelt, or touched anything, or experienced any sudden sensation of warmth or cold, a corresponding effect was produced on the subject, though nothing was said, nor could the subject have seen what had occurred to the operator. To be assured of this he bandaged the girl's eyes with great care, and the operator having gone behind the girl to the other end of the room, he watched him and the girl, and repeatedly assured himself of this fact." Thus far, Professor Barrett's observations, depending in part on what the operator experienced, may be open to just so much doubt as may affect our opinion of the veracity of a person unknown; but in what follows we have his own experience alone to consider. "Having mesmerized the girl himself, he took a card at random from a pack which was in a drawer in another room. Glancing at the card to see what it was, he placed it within a book, and in that state brought it to the girl. Giving her the closed book, he asked her to tell him what he had put within its leaves. She held the book close to the side of her head, and said, 'I see something inside with red spots on it'; and she afterwards said there were five red spots on it. The card was the five of diamonds. The same result occurred with another card; and when an Irish bank-note was substituted for the card, she said, 'Oh, now I see a number of heads—so many that I cannot count them.' He found that she sometimes failed to guess correctly, asserting that the things were dim; and she could give no information of what was within the book unless he had previously known what it was himself. More remarkably still, he asked her to go in imagination to Regent Street, in London, and tell him what shops she had seen. The girl had never been out of her remote village, but she correctly described to him Mr. Ladd's shop, of which he happened to be thinking, and mentioned the large clock that overhangs the entrance to Beak Street. In many other cases he convinced himself that the existence of a distinct idea in his own

mind gave rise to an image of the idea (that is, to a corresponding image) on the mind of the subject; not always a clear image, but one that could not fail to be recognized as a more or less distorted reflection of his own thought." It is important to notice the limit which a scientific observer thus recognized in the range of the subjects' perception. It has been stated that subjects in this condition have been able to describe occurrences not known to any person, which yet have been subsequently verified. Although some narratives of the kind have come from persons not likely to relate what they *knew* to be untrue, the possibility of error outweighs the probability that such narratives can really be true. There is a form of unconscious cerebration by which untruthful narratives come to be concocted in the mind. For instance, Dr. Carpenter heard a scrupulously conscientious lady asseverate that a table "rapped" when nobody was within a yard of it; but the story was disproved by the lady herself, who found from her note-book, recording what really took place, that the hands of six persons rested on the table when it rapped. And apart from the unconscious fiction-producing power of the mind, there is always the possibility, nay, often the extreme probability, that the facts of a case may be understood. Persons may be supposed to know nothing about an event who have been conscious of its every detail; nay, a person may himself be unconscious of his having known, and in fact of his really knowing, of a particular event. Dual consciousness in this particular sense is a quite common experience, as, for instance, when a story is told us which we receive at first as new, until gradually the recollection dawns upon us and becomes momentarily clearer and clearer, not only that we have heard it before, but of the circumstances under which we heard it, and even of details which the narrator from whom a few moments before we receive it as a new story has omitted to mention.*

The most important of all the questions depending on dual consciousness is one into which I could not properly enter at any length in these pages—the question, namely, of the relation between the condition of the brain and responsibility, whether such responsibility be considered with reference to human laws or to a higher and all-knowing tribunal. But there are some points not wanting in interest which may be here more properly considered.

In the first place it is to be noticed that a person who has passed into a state of abnormal consciousness, or who is in the habit of doing so, can have no knowledge of the fact in his normal condition except from the information of others. The boy at Norwood might be told of what he had said and done while in his less usual condition, but so far as any experience of his own was concerned, he might during all that time have been

* An instance of the sort turns up in Pope's correspondence with Addison, and serves to explain a discrepancy between Tickell's edition of the *Spectator* and the original. In No. 253, Addison had remarked that none of the critics had taken notice of a peculiarity in the description of Sisyphus lifting his stone up the hill, which is no sooner carried to the top of it but it immediately tumbles to the bottom. "This double motion," says Addison, "is admirably described in the numbers of those verses. In the four first it is heaved up by several spondees intermixed with proper breathing places, and at last trundles down in a continual line of dactyls." On this Pope remarks: "I happened to find the same in Dionysius of Halicarnassus's Treatise, who treats very largely upon these verses. I know you will think fit to soften your expression, when you see the passage, which you must needs have read, though it be since slipt out of your memory." These words, by the way, were the last (except "I am, with the utmost esteem, &c.") ever addressed by Pope to Addison. It was in this letter that Pope with sly malice asked Addison to look over the first two books of his (Pope's) translation of Homer.

in a profound sleep. Similarly of all the other cases. So that we have here the singular circumstance to consider, that a person may have to depend on the information of others respecting his own behavior—not during sleep or mental aberration or ordinary absence of mind—but (in some cases at least) while in possession of all his faculties and unquestionably responsible for his actions. Not only might a person find himself thus held responsible for actions of which he had no knowledge, and perhaps undeservedly blamed or condemned, but he might find himself regarded as untruthful because of his perfectly honest denial of all knowledge of the conduct attributed to him. If such cases were common, again, it would not improbably happen that the simulation of dual consciousness would become a frequent means of attempting to evade responsibility.

Another curious point to be noticed is this. Supposing one subject to alternations of consciousness were told that in his abnormal condition he suffered intense pain or mental anguish in consequence of particular actions during his normal state, how far would he be influenced to refrain from such actions by the fear of causing pain or sorrow to his "double," a being of whose pains and sorrows, nay, of whose very existence, he was unconscious? In ordinary life a man refrains from particular actions which have been followed by unpleasant consequences, reasoning, in some cases, "I will not do so-and-so, because I suffered on such and such occasions when I did so" (we set religious considerations entirely on one side by assuming that the particular actions are not contrary to any moral law), in others, "I will not do so-and-so, because my so doing on former occasions has caused trouble to my friend A or B;" but it is strange to imagine any one reasoning, "I will not do so-and-so, because my so doing on former occasions has caused my second self to experience pain and anguish, of which I myself have not the slightest recollection." A man may care for his own well-being, or be unwilling to bring trouble on his friends, but who is that second self that his troubles should excite the sympathy of his fellow-consciousness? The considerations here touched on are not so entirely beyond ordinary experience as might be supposed. It may happen to any man to have occasion to enter into an apparently unconscious condition during which in reality severe pains may be suffered by another self, though on his return to his ordinary condition no recollection of those pains may remain, and though to all appearance he has been all the time in a state of absolute stupor; and it may be a reasonable question, not perhaps whether he or his double shall suffer such pains, but whether the body which both inhabit will suffer while he is unconscious, or while that other consciousness comes into existence. That this is no imaginary supposition is shown by several cases in Abercrombie's treatise on the "Intellectual Powers." Take, for instance, the following narrative: "A boy," he tells us, "at the age of four suffered fracture of the skull, for which he underwent the operation of the trepan. He was at the time in a state of perfect stupor, and after his recovery retained no recollection either of the accident or of the operation. At the age of fifteen, however, during the delirium of fever, he gave his mother an account of the operation, and the persons who were present at it, with a correct description of their dress, and other minute particulars. He had never been observed to allude to it before; and no means were known by which he could have acquired the circumstances which he mentioned." Suppose one day a person in the delirium of fever or under some other exciting cause should describe the tortures experienced during some operation, when, under the influence of anæsthetics, he had appeared to all around to be totally unconscious, dwelling in a special man

ner perhaps on the horror of pains accompanied by utter powerlessness to shriek or groan, or even to move; how far would the possibilities suggested by such a narrative influence one who had a painful operation to undergo, knowing as he would quite certainly, that whatever pains his *alter ego* might have to suffer, not the slightest recollection of them would remain in his ordinary condition?

There is indeed almost as strange a mystery in unconsciousness as there is in the phenomena of dual consciousness. The man who has passed for a time into unconsciousness through a blow, or fall, or fit, cannot help asking himself Like Bernard Langdon in that weird tale Elsie Venner, "Where was the mind, the soul, the thinking principle all the time?" It is irresistibly borne in upon him that he has been dead for a time. As Holmes reasons, "a man is stunned by a blow and becomes unconscious, another gets a harder blow and it kills him. Does he become unconscious too? If so, *when*, and *how does he come to his consciousness?* The man who has had a slight and moderate blow comes to himself when the immediate shock passes off and the organs begin to work again, or when a bit of skull is 'pried' up, if that happens to be broken. Suppose the blow is hard enough to spoil the brain and stop the play of the organs, what happens then?" So far as physical science is concerned, there is no answer to this question; but physical science does not as yet comprehend all the knowable and the knowable comprehends not all that has been, is, and will be. What we know and can know is nothing, the unknown and the unknowable are alike infinite.

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FASHION IN DEFORMITY

AS ILLUSTRATED IN THE

CUSTOMS OF BARBAROUS AND CIVILIZED RACES

By WILLIAM HENRY FLOWER

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WITH ILLUSTRATIONS.

TO WHICH IS ADDED:

MANNERS AND FASHION

By HERBERT SPENCER

FASHION IN DEFORMITY.

The propensity to *deform*, or alter from the natural form, some part of the body, is one which is common to human nature in every aspect in which we are acquainted with it, the most primitive and barbarous, and the most civilized and refined.

The alterations or deformities which it is proposed to consider in this essay, are those which are performed, not by isolated individuals, or with definite motives, but by considerable numbers of members of a community, simply in imitation of one another—in fact, according to *fashion*, "that most inexorable tyrant to which the greater part of mankind are willing slaves."

Fashion is now often associated with change, but in less civilized conditions of society fashions of all sorts are more permanent than with us; and in all communities such fashions as those here treated of are, for obvious reasons, far less likely to be subject to the fluctuations of caprice than those affecting the dress only, which, even in Shakespeare's time, changed so often that "the fashion wears out more apparel than the man." Alterations once made in the form of the body cannot be discarded or modified in the lifetime of the individual, and therefore, as fashion is intrinsically imitative, such alterations have the strongest possible tendency to be reproduced generation after generation.

The origins of these fashions are mostly lost in obscurity, all attempts to

solve them being little more than guesses. Some of them have become associated with religious or superstitious observances, and so have been spread and perpetuated; some have been vaguely thought to be hygienic in motive; most have some relation to conventional standards of improved personal appearance; but whatever their origin, the desire to conform to common usage, and not to appear singular, is the prevailing motive which leads to their continuance. They are perpetuated by imitation, which, as Herbert Spencer says, may result from two widely divergent motives. It may be prompted by reverence for one imitated, or it may be prompted by the desire to assert equality with him.

Before treating of the subject in its application to the human body, it will be well to glance, in passing, at the fact that a precisely similar propensity has impelled man, at various ages of the world's history, and under various conditions of society, to interfere in the same manner with the natural conformation of many of the animals which have come under his influence through domestication.

The Hottentots, objecting to symmetry of growth in the horns of their cattle, twist them while young and pliant, so that ultimately they are made to assume various fantastic and unnatural directions. Sheep with multiple horns are produced in some parts of Africa by splitting with a knife the budding horn of the young animal. Hotspur's exclamation, "What horse? a roan, a *crop-ear*, is it not?" points to a custom not yet extinct in England. Docking horses' tails—that is, cutting off about half the length, not of the hair only, but of the actual flesh and bone, and *nicking*, or dividing the tendons of the under side, so that the paralyzed stump is always carried in an unnatural or "cocked" position—were common enough a generation ago, as seen in all equestrian pictures of the period, and are still occasionally practised. In spite of all warnings of common sense and experience, we continue, solely because it is the fashion, to torture and deform our horses' mouths and necks with tight bearing-reins, which though only temporarily keeping the head in a constrained and unnatural, and therefore inelegant position, produce many permanent injuries.* Dogs may still be seen with the natural form of their ears and tails "improved" by mutilation.

Besides these and many other modifications of the form given by nature, practised upon the individual animal, selective breeding through many generations has succeeded in producing inherited structural changes, sometimes of very remarkable character. These have generally originated in some accidental, perhaps slight, peculiarity, which has been taken advantage of, perpetuated and increased. In this way the race of bull-dogs, with their shortened upper jaws, bandy legs and twisted tails, have been developed. The now fashionable "dachshund" is another instance. In this category may also be placed polled and humped cattle, tailless cats of the Isle of Man and Singapore, lop-eared rabbits, tailless, crested, or other strange forms of fowls; pouter, tumbler, feather-legged, and other varieties of pigeons; and the ugly double-tailed and prominent-eyed goldfish which delight the Chinese. Thus the power which, when judiciously exercised, has led to the vast improvement seen in many domestic species over their wild progenitors, has also ministered to strange vagaries and caprices, in the production and perpetuation of monstrous forms.

To return to man, the most convenient classification of our subject will be one which is based upon the part of the body affected, and I will begin with the treatment of the hair and other appendages of the skin as the more superficial and comparatively trivial in its effects.

Here we are at once introduced to the domain of fashion in her most potent sway. The facility with which hair lends itself to various methods of treatment has been a temptation too great

* See "Bits and Bearing Reins," by Edward Fordham Flower. London, 1879.

to resist in all known conditions of civilization. Innumerable variations of custom exist in different parts of the world, and marked changes in at least all more or less civilized communities have characterized successive epochs of history. Not only the length and method of arrangement, but even the color of the hair, is changed in obedience to caprices of fashion. In many of the islands of the Western Pacific, the naturally jet black hair of the natives is converted into a tawny brown by the application of lime, obtained by burning the coral found so abundantly on their shores ; and not many years since similar means were employed for producing the same result among the ladies of Western Europe — a fact which considerably diminishes the value of an idea entertained by many ethnologists, that community of custom is evidence of community of origin or of race.

Notwithstanding the painful and laborious nature of the process, when conducted with no better implements than flint knives, or pieces of splintered bone or shell, the custom of keeping the head closely shaved prevails extensively among savage nations. This, doubtless, tends to cleanliness, and perhaps comfort, in hot countries ; but the fact that it is in many tribes practised only by the women and children, shows that these considerations are not those primarily engaged in its perpetuation. In some cases, as among the Fijians, while the heads of the women are commonly cropped or closely shaved, the men cultivate, at great expense of time and attention, a luxuriant and elaborately arranged mass of hair, exactly reversing the conditions met with in the most highly civilized nations.

In some regions of Africa it is considered necessary to female beauty carefully to eradicate the eyebrows, special pincers for the purpose forming part of the appliances of the toilette ; while the various methods of shaving and cutting the beard among men of all nations are too well known to require more than a passing notice. The treatment of finger nails, both as to color and form, has also been subject to fashion ; but the practical inconveniences attending the inordinate length to which these are permitted to grow in some parts of the east of Asia appear to have restricted the custom to a few localities. (See Fig. 1.)

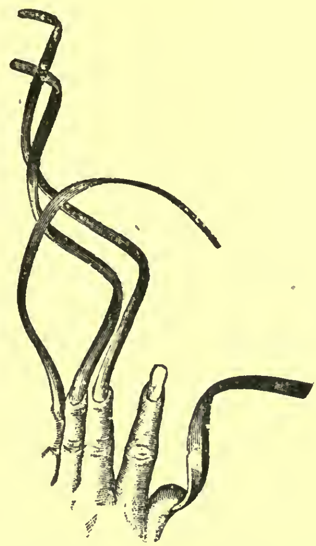

Fig. 1.—Hand of Chinese Ascetic, from Tylor's "Anthropology."

It may be objected to the introduction of this illustration here, that such nails should not be considered deformities, but rather as natural growth, and that to clip and mutilate them as we do is the departure from nature's intention. But this is not so. It is only by constant artificial care and protection that such an extraordinary and inconvenient length can be obtained. When the hands are subjected to the normal amount of use, the nails break or wear away at their free ends in a ratio equal to their growth, as with the claws or hoofs of animals in a wild state.

The exceedingly widespread custom of tattooing * the skin, may also be alluded to here, as the result of the same

* A word used by the natives of Tahiti, spelt *tattowing* by Cook, who gives a minute account of the method in which it is performed in that island. "First Voyage," vol. ii., p. 191.

propensity as that which produces the more serious deformations presently to be spoken of. The rudest form of the art was practised by the now extinct Tasmanians and some tribes of Australians, whose naked bodies showed linear or oval raised scars, arranged in a definite manner on the shoulders and breast, and produced by gashes inflicted with sharp stones, into which wood-ashes were rubbed, so as to allow of healing only under unfavorable conditions, leaving permanent large and elevated cicatrices, conspicuous from being of a lighter color than the rest of the skin. From this it is a considerable step in decorative art to the elaborate and often beautiful patterns, wreaths, scrolls, spirals, zigzags, etc., sometimes confined to the face, and sometimes covering the whole body from head to foot, seen in the natives of many of the Polynesian Islands. These are permanently impressed upon the skin, by the introduction of coloring matter, generally some kind of lamp-black, by means of an instrument made of a piece of shell cut into a number of fine points, or a bundle of sharp needles. When the custom of the land demands that the surface to be treated thus is a large one, the process is not only very tedious, but entails an amount of suffering painful to think of. When completed it answers part at least of the purpose of dress with us, as an untattooed skin exhibited to society is looked upon much as an unclothed one would be in more civilized communities. The natural color of the skin seems to have influenced the method and extent of tattooing, as in the black races it is limited to such scars as those spoken of above; which, variously arranged in lines or dots, become tribal distinctions among African negroes. In Europe tattooing on the same principle as that of the Polynesians, is confined almost exclusively to sailors, among whom it is kept up obviously by imitation or fashion.

The nose, the lips, and the ears have in almost all races offered great temptations to be used as foundations for the display of ornament, some process of boring, cutting, or alteration of form being necessary to render them fit for the purpose. When Captain Cook, exactly one hundred years ago, was describing the naked savages of the east coast of Australia,* he says: "Their principal ornament is the bone which they thrust through the cartilage which divides the nostrils from each other.

Fig. 2.—Australian Native, with bone nose-ornament.

What perversion of taste could make them think this a decoration, or what could prompt them, before they had worn it or seen it worn, to suffer the pain and inconvenience that must of necessity attend it, is perhaps beyond the power of human sagacity to determine. As this bone is as thick as a man's finger, and between five and six inches long, it reaches quite across the face, and so effectually stops up both the nostrils that they are forced to keep their mouths wide open for breath, and snuffle so when they attempt to speak that they are scarcely intelligible even to each other. Our seamen, with some humor, called it their spritsail-yard; and indeed it had so ludicrous an appearance, that till we were used to it we found it difficult to refrain from laughter."

Eight years later, on his visit to the northwest coast of America, Captain

* "First Voyage," vol. ii., p. 633.

Cook found precisely the same custom prevailing among the natives of Prince William's Sound, whose mode of life was in most other respects quite dissimilar to that of the Australians, and who belong ethnologically to a totally different branch of the human race.

In 1681 Dampier * thus describes a custom which he found existing among the natives of the Corn Islands, off the Moskuito coast, in Central America : "They have a fashion to cut holes in the Lips of the Boys when they are young, close to their Chin, which they keep open with little Pegs till they are 14 or 15 years old ; then they wear Beards in them, made of Turtle or Tortoise-shell, in the form you see in the Margin. (See Fig. 3.) The little notch at the upper end they put in through the Lip, where it remains between the Teeth and the Lip ; the under part hangs down over their Chin.

FIG. 3.—Tortoise-shell lip ornament of the Moskito Indians. From Dampier.

This they commonly wear all day, and when they sleep they take it out. They have likewise holes bored in their Ears, both Men and Women, when young, and by continual stretching them with great Pegs, they grow to be as big as a mill'd five Shilling Piece. Herein they wear pieces of Wood, cut very round and smooth, so that their Ear seems to be all wood, with a little Skin about it."

It is very remarkable that an almost exactly similar custom still prevails among a tribe of Indians inhabiting the southern part of Brazil—the Botocudos, so called from a Portuguese word (*botoque*) meaning a plug or stopper. Among these people the lip-ornament consists of a conical piece of hard and polished wood, frequently weighs a quarter of a pound, and drags down, elongates, and everts the lower lip, so as to expose the gums and teeth, in a manner which to our taste is hideous, but with them is considered an essential adjunct to an attractive and correct appearance.

In the extreme north of America, the Eskimo "pierce the lower lip under one or both corners of the mouth, and insert in each aperture a double-headed sleeve-button or dumb-bell shaped labret, of bone, ivory, shell, stone, glass, or wood. The incision when first made is about the size of a quill, but as the aspirant for improved beauty grows older, the size of the orifice is enlarged until it reaches the width of half to three-quarters of an inch." * These operations appear to be practised only on the men, and are supposed to possess some significance other than that of mere ornament. The first piercing of the lip, which is accompanied by some solemnity as a religious feast, is performed on approaching manhood.

But the people who, among the various American tribes, have carried these strange customs to the greatest excess are the Thlinkeets, who inhabit the south-eastern shores of Alaska.† "Here it is the women who, in piercing the nose and ears, and filling the apertures with bones, shells, sticks, pieces of copper, nails, or attaching thereto heavy pendants, which drag down the organs and pull the features out of place, appear to have taxed their inventive powers to the utmost, and with a success unsurpassed by any nation in the world, to produce a model of hideous beauty. This success is achieved in their wooden lip-ornament, the crowning glory of the Thlinkeet

* "Voyage Round the World," ed. 1717, vol. i., p. 32.

* H. H. Bancroft, "Native Races of the Pacific States of North America," vol. i., 1875.

† See Bancroft, op. cit. vol. i., for numerous citations from original observers regarding these customs.

matron, described by a multitude of eye-witnesses. In all female free-born Thlinkeet children a slit is made in the under lip, parallel with the mouth, and about half an inch below it. A copper wire, or a piece of shell or wood, is introduced into this, by which the wound is kept open and the aperture extended. By gradually introducing larger objects the required dimensions of the opening are produced. On attaining the age of maturity, a block of wood is inserted, usually oval or elliptical in shape, concave on the sides, and grooved like the wheel of a pulley on the edge in order to keep it in place. The dimensions of the block are from two to six inches in length, from one to four inches in width, and about half an inch thick round the edge, and it is highly polished. Old age has little terror in the eyes of a Thlinkeet belle ; for larger lip-blocks are introduced as years advance, and each enlargement adds to the lady's social status, if not to her facial charms. When the block is withdrawn, the lip drops down upon the chin like a piece of leather, displaying the teeth, and presenting altogether a ghastly spectacle. The privilege of wearing this ornament is not extended to female slaves."

FIG. 4.—Botocudo Indian.
From Bigg-Wither's "Pioneering in South Brazil (1878)."

In this method of adornment the North Americans are, however, rivalled, if not eclipsed, by the negroes of the heart of Africa.

"The Bongo women" (says Schweinfurth *) "delight in distinguishing themselves by an adornment which to our notion is nothing less than a hideous mutilation. As soon as a woman is married, the operation commences of extending her lower lip. This, at first only slightly bored, is widened by inserting into the orifice plugs of wood, gradually increasing in size, until at length the entire feature is enlarged to five or six times its original proportions. The plugs are cylindrical in form, not less than an inch thick, and are exactly like the pegs of bone or wood worn by the women of Musgoo. By this means the lower lip is extended horizontally till it projects far beyond the upper, which is also bored and fitted with a copper plate or nail, and now and then by a little ring, and sometimes by a bit of straw, about as thick as a lucifer-match. Nor do they leave the nose intact ; similar bits of straw are inserted into the edges of the nostrils, and I have seen as many as three of these on each

* "Heart of Africa," vol. i., p. 297.

side. A very favorite ornament for the cartilage between the nostrils is a copper ring, just like those that are placed in the noses of buffaloes and other beasts of burden for the purpose of rendering them more tractable. The greatest coquettes among the ladies wear a clasp, or cramp, at the corners of the mouth, as though they wanted to contract the orifice, and literally to put a curb upon its capabilities. These subsidiary ornaments are not, however, found at all universally among the women, and it is rare to see them all at once upon a single individual; the plug in the lower lip of the married women is alone a *sine quâ non*, serving, as it does, for an artificial distinction of race."

The slightest fold or projection of the skin furnishes an excuse for boring a hole, and inserting a plug or a ring. There are women in the country whose bodies are pierced in some way or other in little short of a hundred different places, and the men are often not far behind in the profusion with which this kind of adornment is carried out.

"The whole group of the Mittoo exhibits peculiarities by which it may be distinguished from its neighbors. The external adornment of the body, the costume, the ornaments, the mutilations which individuals undergo — in short, the general fashions—have all a distinctive character of their own. The most remarkable is the revolting, because unnatural, manner in which the women pierce and distort their lips; they seem to vie with each other in their mutilations; and their vanity in this respect, I believe, surpasses anything that may be found throughout Africa. Not satisfied with piercing the lower lip, they drag out the upper lip as well for the sake of symmetry.* . . . Circular plates, nearly as large as a crown piece, made variously of quartz, of ivory, or of horn, are inserted into the lips that have been stretched by the growth of years, and then often bent in a position that is all but horizontal; and when the women want to drink they have to elevate the upper lip with their fingers, and to pour the draught into their mouth.

FIG. 5.—Loobah Woman.
From Schweinfurth's "Heart of Africa."

"Similar in shape is the decoration which is worn by the women of Maganya; but though it is round, it is a ring and not a flat plate; it is called 'pelele,' and has no object but to expand the upper lip. Some of the Mittoo women, especially the Loobah, not content with the circle or the ring, force a cone of polished quartz through the lips as though they had borrowed the idea from the rhinoceros. This fashion of using quartz belemnites of more than two inches long, is in some instances adopted by the men."

The traveller who has been the eyewitness of such customs may well add, "Even among these uncultured children of nature, human pride crops up among the fetters of fashion, which, indeed, are fetters in the worst sense of the word; for fashion in the distant wilds of Africa tortures and harasses poor humanity as much as in the great prison of civilization."

It seems, indeed, a strange phenomenon that in such different races, so far removed in locality, customs so singular —to our ideas so revolting and unnatural, and certainly so painful and in-

* The mutilation of both lips was also observed by Rohlfs among the women of Kadje, in Segseg, between Lake Tsad and the Benwe.

convenient—should either have been perpetuated for an enormous lapse of time, if the supposition of a common origin be entertained, or else have developed themselves independently.

These are, however, only extreme or exaggerated cases of the almost universal custom of making a permanent aperture through the lobe of the ear for the purpose of inserting some adventitious object by way of adornment, or even for utility, as in the man of the Island of Mangea, figured in Cook's voyages, who carries a large knife through a hole in the lobe of the right ear. The New Zealanders of both sexes, when first visited by Europeans, all had holes bored through their ears, and enlarged by stretching, and which in their domestic economy answered the purpose of our pockets. Feathers, bones, sticks, talc chisels and bodkins, the nails and teeth of their deceased relations, the teeth of dogs, and in fact anything which they could get that they thought curious or valuable, were thrust through or suspended to them. The iron nails given them by the English sailors were at once conveyed to these miscellaneous receptacles.* The Zulus lately exhibited in London carried their cigars in the same manner. Mr. Wilfred Powell informs me that he met with a man on one of the islands near New Guinea, the holes in whose ears had been extended to such an extent that the lobes had been converted into great pendent rings of skin, through which he could easily pass his arms!

Among ourselves the custom of wearing ear-rings still survives, even in the highest grades of society, although it has been almost entirely abandoned by one-half of the community, and in the other the perforation is reduced to the smallest size compatible with the purpose of carrying the ornament suspended from it. Nose-rings are not now the fashion in Europe, but the extent to which they are admired in the East may be judged of by the frequency with which they are worn by the ayahs or female servants who so often accompany English families returning from India.

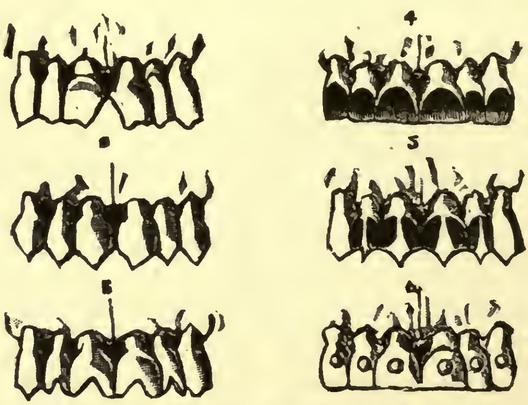

FIG. 6.—Upper front teeth altered according to fashion.
1, 2, 3, African; 4, 5, 6, Malay.

The teeth, although allowed by the greater part of the world to retain their natural beauty and usefulness of form, still offer a field for artificial alterations according to fashion, which has been made use of principally in two distinct regions of the world and by two distinct races. It is, of course, only the front teeth, and mainly the upper incisors, that are available for this purpose. Among various tribes of negroes of Equatorial Africa different fashions of modifying the natural form of these teeth prevail, specimens of which may

* Cook's "First Voyage," vol. iii., p. 456.

be found in any large collection of crania of these people. One of the simplest consists of chipping and filing away a large triangular piece from the lower and inner edge of each of the central incisors, so that a gap is produced in the middle of the row in front (Fig. 6, 1). Another fashion is to shape all the incisors into sharp points, by chipping off the corners, giving a very formidable crocodilian appearance to the jaws (2) ; and another is to file out either a single or a double notch in the cutting edge of each tooth, producing a serrated border to the whole series (3).

The Malays, however, excel the Africans both in the universality and in the fantastic variety of their supposed improvements upon nature. While the natural whiteness of the surface of these organs is always admired by us, and by most people, the Malays take the greatest pains to stain their teeth black, which they consider greatly adds to their beauty. White teeth are looked upon with perfect disgust by the Dayaks of the neighborhood of Sarawak. In addition to staining the teeth, filing the surface in some way or other is almost always resorted to. The nearly universal custom in Java is to remove the enamel from the front surface of the incisors, and often the canine teeth, hollowing out the surface, sometimes so deeply as to penetrate the pulp cavity (Fig. 6, 4). The cutting edges are also worn down to a level line with pumice-stone. Another and less common, though more elaborate fashion, is to point the teeth, and file out notches from the anterior surface of each side of the upper part of the crown, so as to leave a lozenge-shaped piece of enamel untouched ; as this receives the black stain less strongly than the parts from which the surface is removed, an ornamental pattern is produced (5). In Borneo a still more elaborate process is adopted, the front surface of each of the teeth is drilled near its centre with a small round hole, and into this a plug of brass with a round or star-shaped knob is fixed (6). This is always kept bright and polished by the action of the lip over it, and is supposed to give a highly attractive appearance when the teeth are displayed. A skull with the teeth treated in this way may be seen in the Barnard Davis Collection, now in the Museum of the Royal College of Surgeons.

The Javan practice appears also to prevail in fashionable circles in the neighboring parts of the mainland of Asia. The Siamese envoy who visited this country in 1880 had his upper incisor teeth treated like No. 4, Fig. 6, and one of his suite had them pointed.

Perhaps the strange custom, so frequently adopted by the natives of Australia, and of many islands of the Pacific, of knocking out one or more of the front teeth, might be mentioned here, but it is usually associated with some other idea than ornament or even mere fashion. In the first-named country it constitutes part of the rites by which the youth are initiated into manhood, and in the Sandwich Islands it is performed as a propitiatory sacrifice to the spirits of the dead.

The projection forward of the front upper teeth, which we think unbecoming, is admired by some races, and among the negro women of Senegal it is increased by artificial means employed in childhood.*

All these modifications of form of comparatively external and flexible parts are, however, trivial in their effects upon the body to those to be spoken of next, which induce permanent structural alterations both upon the bony framework and upon the important organs within.

Whatever might be the case with regard to the hair, the ears, the nose, and lips, or even the teeth, it might have been thought that the actual shape of the head, as determined by the solid skull, would not have been considered a subject to be modified according to the fashion of the time and place. Such, however, is far from being the case. The custom of artificially changing the form of the head is one of the

* Hamy, "Revue d'Anthropologie," Jan. 1879, p. 22.

most ancient and widespread with which we are acquainted. It is far from being confined, as many suppose, to an obscure tribe of Indians on the northwest coast of America, but is found under various modifications at widely different parts of the earth's surface, and among people who can have had no intercourse with one another. It appears, in fact, to have originated independently in many quarters, from some natural impulse common to the human race. When it once became an established custom in any tribe, it was almost inevitable that it should continue, until put an end to by the destruction either of the tribe itself, or of its peculiar institutions, through the intervention of some superior force; for a standard of excellence in form, which could not be changed in those who possessed it, was naturally followed by all who did not wish their children to run the risk of the social degradation which would follow the neglect of such a custom. "Failure properly to mould the cranium of her offspring gives to the Chinook * matron the reputation of a lazy and undutiful mother, and subjects the neglected children to the ridicule of their young companions, so despotic is fashion." † A traveller, who mentions that he occasionally saw Chinooks with heads of the ordinary shape, sickness or some other cause having prevented the usual distortion in infancy, adds that such individuals could never attain to any influence or rise to any dignity in their tribe, and were not unfrequently sold as slaves. ‡

It is related in the narrative of Commodore Wilkes' United States Exploring Expedition, § that "at Niculuita Mr. Drayton obtained the drawing of a child's head, of the Wallawalla tribe (Fig. 7), that had just been released from its bandages, in order to secure its flattened shape. Both the parents showed great delight at the success they had met with in effecting this distortion."

Endeavors have been made to trace the origin of this and many analogous customs to a desire to intensify or exaggerate any prevailing natural peculiarity of conformation. Thus races in which the forehead is naturally low are supposed to have admired, a[illegible] then to have artificially imitated, [illegible]i-viduals in which the peculiarit[illegible]s most pronounced. But this assumption does not rest upon any strong basis of

FIG. 7.—Flat-headed Indian Child.

fact. The motives assigned by the native Peruvians for their interference with the natural form of their children's heads, as reported by the early Spanish historians, were very various. Some said that it contributed to health, and enabled them to bear greater burdens; others that it increased the ferocity of the countenance in war.* These were all probably excuses for a blind adherence to custom or the imperious demands of fashion.

Many of the less severe alterations of the form to which the head is subjected are undesigned, resulting only from the mode in which the child is carried or dressed during infancy. Thus habitually carrying the child on one arm appears to produce an obliquity in the form of the skull which is retained to a greater or less degree all through life. The practice followed by nomadic people of carrying their infants fastened

* A tribe of Indians inhabiting the neighborhood of the Columbia River, North America.

† Bancroft, op. cit. vol. i., p. 238.

‡ T. K. Townsend, "Journey to the Columbia River," p. 175.

§ Vol. iv., p. 388.

* Morton's "Crania Americana," p. 116.

to stiff pillows or boards, commonly causes a flattening of the occiput ; and the custom of dressing the child's head with tightly fitting bandages, still common in many parts of the Continent, and even used in England within the memory of living people, produces an elongated and laterally constricted form.* In France this is well known, and so common is it in the neighborhood of Toulouse, that a special form of head produced in this manner is known as the "*déformation Toulousaine.*"

Of the ancient notices of the custom of purposely altering the form of the head, the most explicit is that of Hippocrates, who in his treatise "De Aëris, Aquis et Locis," written about 400 B.C., says,† speaking of the people near the boundary of Europe and Asia, near the *Palus Mæotis* (Sea of Azoff) : "I will pass over the smaller differences among the nations, but will now treat of such as are great either from nature or custom ; and first, concerning the *Macrocephali.* There is no other race of men which have heads in the least resembling theirs. At first, usage was the principal cause of the length of their head, but now nature co-operates with usage. They think those the most noble who have the longest heads. It is thus with regard to the usage : immediately after the child is born, and while its head is still tender, they fashion it with their hands, and constrain it to assume a lengthened shape by applying bandages and other suitable contrivances, whereby the spherical form of the head is destroyed, and it is made to increase in length. Thus, at first, usage operated, so that this constitution was the result of force ; but in the course of time it was formed naturally, so that usage had nothing to do with it."

Here, Hippocrates appears to have satisfied himself upon a point which is still discussed with great interest, and still not cleared up—the possibility of transmission by inheritance of artificially produced deformity. Some facts seem to show that such an occurrence may take place occasionally, but there is an immense body of evidence against its being habitual.

Herodotus also alludes to the same custom, as do, at later dates, Strabo, Pliny, Pomponius Mela and others, though assigning different localities to the nations or tribes to which they refer, and also indicating variations of form in their peculiar cranial characteristics.

Recent archæological discoveries fully bear out these statements. Heads deformed in various fashions, but chiefly of the constricted, elongated shape, have been found in great numbers in ancient tombs, in the very region indicated by Herodotus. They have been found near Tiflis, where as many as 150 were discovered at one time, and at other places in the Caucasus, generally in rock tombs ; also in the Crimea, and at different localities along the course of the Danube ; in Hungary, Silesia, in the South of Germany, Switzerland, and even in France and Belgium. The people who have left such undoubted evidence of the practice of deforming their heads have been supposed by various authors to have been Avars, Huns, Tartars, or other Mongolian invaders of Europe ; but later French authors who have discussed this subject are inclined to assign them to an Aryan race, who, under the name of Cimmerians, spread westward over the part of Europe in which their remains are now found, in the seventh or eighth century before our era. Whether the French habit, scarcely yet extinct, of tightly bandaging the heads of infants, is derived from these people, or is of independent origin, it is impossible to say.

There is no unequivocal proof that the custom of designedly altering the form of the head ever existed in this country, but the singular shape of a skull found in 1853 in a Saxon grave at

* A gentleman of advanced age lately showed me a circular depression round the upper part of his head, which he believed had been produced in this manner, as the custom was still prevailing at the time of his birth in the district of Norfolk, of which he was a native.

† Sydenham Society's edition, by Dr. Adams, vol. i., p. 270.

West Harnham, in Wilts, figured and described in Davis's and Thurnam's "Crania Britannica," and now in the Museum of the College of Surgeons, is apparently due to such a cause.

In Africa and Australia no analogous customs have been shown to exist, but in many parts of Asia and Polynesia, deformations, though usually only confined to flattening of the occiput, are common. Though often undesigned, they are done purposely, I am informed by Mr. H. B. Low, by the Dayaks, in the neighborhood of Sarawak. Sometimes, in the islands of the Pacific, the head of the new-born infant is merely pressed by the hands into the desired form, in which case it generally soon recovers that which nature intended for it. In one island alone, Mallicollo, in the New Hebrides, the practice of permanently depressing the forehead is almost universal, and skulls are even found constricted and elongated exactly after the manner of the Aymaras of ancient Peru. The extraordinary flatness of the forehead, by which the inhabitants of this island differ from those of all around, was noticed by Captain Cook and the two Forsters, who accompanied him as naturalists, but they were not able to ascertain whether it was a natural conformation or due to art. It is only within the last few years that crania have been sent to England which abundantly confirm the old description of the great navigator, and also prove the artificial character of the deformity.

Though the Chinese usually allow the head to assume its natural form, confining their attentions to the feet, a certain class of mendicant devotees appear to have succeeded to a remarkable extent in getting their skulls elongated into a conical form, if the figure in Picart's "Histoire des Religions," vol. iv., plate 131, is to be trusted.

America is, however, or rather has been, the headquarters of all these fantastic practices, and especially along the western coast, and mainly in two regions, near the mouth of the Columbia River in the north, and in Peru in the south. The practice also existed among the Indians of the southern parts of what are now the United States, and among the Caribs of the West India Islands. In ancient Peru, before the time of the Spanish conquest, it was almost universal. In an edict of the ecclesiastical authorities of Lima, issued in 1585, three distinct forms of deformation are mentioned. Notwithstanding the severe penalties imposed by this edict upon parents persisting in the practice, the custom was so difficult to eradicate that another injunction

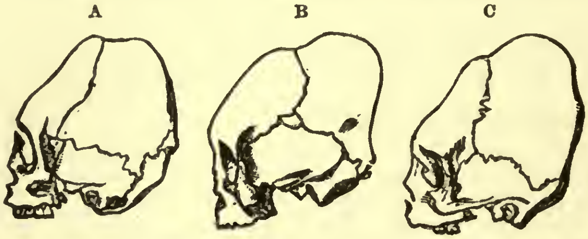

Fig. 8.—Skulls artificially deformed according to similar fashions. A, from an ancient tomb at Tiflis; B, from Titicaca, Peru; C, from the island of Mallicollo, New Hebrides. (From specimens in the Museum of the Royal College of Surgeons.)

Fig. 9.—Deformed Skull of an Infant who had died during the process of flattening. From the Columbia River. (Mus. Roy. Coll. Surgeons.)

against it was published by the government as late as 1752.

In the West Indies, and the greater part of North America, the custom has become extinct with the people who

FIG. 10.—Artificially flattened Skull of ancient Peruvian. (Mus. Roy. Coll. Surgeons.)

used it; but the Chinook Indians, of the neighborhood of the Columbia River, and the natives of Vancouver Island, continue it to the present day; and this is the last stronghold of this strange fashion, though under the influence of European example and discouragement it is rapidly dying out. Here the various methods of deforming the head, and their effects, have been studied and described by numerous travellers. The process commences immediately after the birth of the child, and is continued for a period of from eight to twelve months, by which time the head has permanently assumed the required form, although during subsequent growth it may partly regain its proper shape. "It might be supposed," observes Mr. Kane, who had large opportunities of watching the process, "that the operation would be attended with great suffering; but I never heard the infants crying or moaning, although I have seen their eyes seemingly starting out of the sockets from the great pressure; but, on the contrary, when the thongs were loosened and the pads removed, I have noticed them cry until they were replaced. From the apparent dulness of the children while under the pressure, I should imagine that a state of torpor or insensibility is induced, and that the return to consciousness occasioned by its removal must be naturally followed by a sense of pain."

Nearly, if not all, the different fashions in cranial deformity, observed in various parts of the world, are found associated within a very small compass in British Columbia and Washington Territory, each small tribe having often a particular method of its own. Many attempts have been made to classify

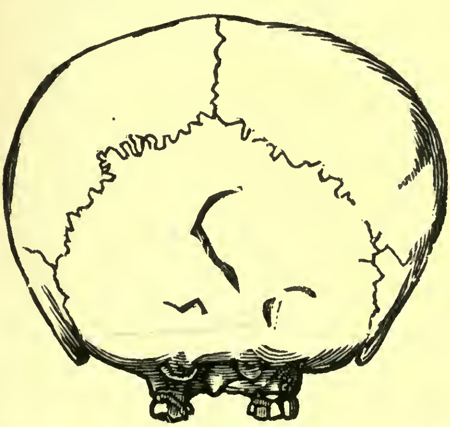

FIG. 11.—Posterior view of Cranium, deformed according to the fashion of flattening, with cor pensatory lateral widening. (Mus. Roy. Coll. Surgeons.)

these various deformities; but as they mostly pass insensibly into one another, and vary according as the intention has been carried out with a greater or less degree of perseverance and skill, it is not easy to do so. Besides the simple occipital and the simple frontal compressions, all the others may be grouped into two principal divisions. First (Figs. 9, 10, and 11), that in which the skull is flattened between boards or pads made (among the Indians of the Columbia River) of deer-skin stuffed with frayed cedar bark or moss, applied to the forehead and back of the head; and as there is no lateral pressure, it bulges out sideways, as seen in Fig. 11, to compensate for the shortening in the

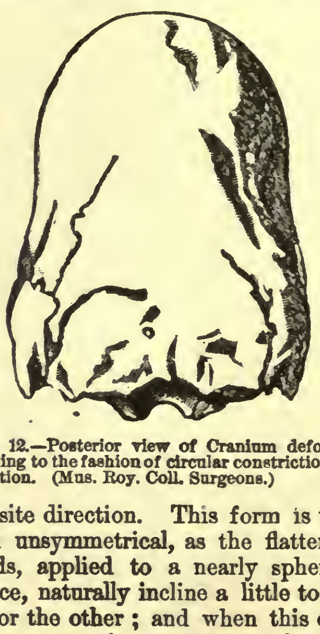

FIG. 12.—Posterior view of Cranium deformed according to the fashion of circular constriction and elongation. (Mus. Roy. Coll. Surgeons.)

opposite direction. This form is very often unsymmetrical, as the flattening boards, applied to a nearly spherical surface, naturally incline a little to one side or the other; and when this once commences, unless great care is used, it must increase until the very curious oblique flattening so common in these skulls is produced. This is the ordinary form of deformity among the Chinook Indians of the Columbia River, commonly called "Flatheads." It is also most frequent among the Quichuas of Peru.

The methods by which this particular kind of deformity was produced varied in detail in different tribes. One of the most effective is thus described by Mr. Townsend: "The Wallamet Indians place the infant, soon after birth, upon a board, to the edges of which are attached little loops of hempen cord or leather; and other similar cords are passed across and back, in a zigzag manner, through these loops, inclosing the child and binding it firmly down. To the upper edge of this board, in which is a depression to receive the back part of the head, another smaller one is attached by hinges of leather, and made to lie obliquely upon the forehead, the force of the pressure being regulated by several strings attached to its edge, which are passed through holes in the board upon which the infant is lying, and secured there."

The second form of deformity (Figs. 8, 12, and 13) is produced by constricting bandages of deer's hide, or other similar material, encircling the head behind the ears, usually passing below the occiput behind, and across the forehead, and again across the vertex, behind the coronal suture, producing a circular depression. The result is an elongation of the head, but with no lateral bulging and with no deviation from bilateral symmetry. This was the form adopted, with trifling modifications, by the *Macrocephali* of Herodotus, by the Aymara Indians of Peru, and by certain tribes, as the Koskeemos, of Vancouver Island. The "*déformation Toulousaine*" is a variation of the same form. Another modification is thus described in Wilson's "Prehistoric Man:" "The Newatees, a warlike tribe on the north end of Vancouver's Island, give a conical shape to the head by means of a thong of deer's skin, padded with the inner bark of the cedar-tree frayed until it assumes the consistency of very soft tow. This forms a cord about the thickness of a man's thumb, which is wound round the infant's head, compressing it gradually into a uniformly tapering cone. The effect of this singular form of head is still further increased by the fashion of gathering the hair into a knot on the crown of the

head." A "sugar-loaf" form of skull has also been found in an ancient grave in France, at Voiteur in the Department of Jura.

The brain, of course, has to accommodate itself to the altered shape of the osseous case which contains it; and the question naturally arises, whether the important functions belonging to this organ are in any way impaired or affected by its change of form. All observations upon the living Indians who have been subjected to it concur in showing that if any modification in mental power is produced, it must be of a very inconsiderable kind, as no marked difference has been detected between them and the people of neighboring tribes which have not adopted the fashion. Men whose heads have been deformed to an extraordinary extent, as Concomly, a Chinook chief, whose skull is preserved in the museum at Haslar Hospital, have often risen by their own abilities to considerable local eminence; and the fact that the relative social position of the chiefs, in whose families the heads are always deformed, and the slaves on whom it is never permitted, is constantly maintained, proves that the former evince no decided inferiority in intelligence or energy.

Of the Newatees, mentioned above, Wilson says, "The process seems neither to affect the intellect nor the courage of the people, who are remarkable for cunning, as well as fierce daring, and are the terror of surrounding tribes."

Of the Mallicollese it is expressly stated by George Forster that "they are the most intelligent people we have ever met with in the South Seas; they understood our signs and gestures as if they had been long acquainted with them, and in a few minutes taught us a great number of words. . . . Thus what they wanted in personal attraction they made up in acuteness of understanding." Cook gives some remarkable instances of the honesty of the "ape-like nation," as he calls them.

Fig. 13.—Cranium of Koskeemo Indian, Vancouver Island, deformed by circular constriction and elongation. (Mus. Roy. Coll. Surgeons.)

Although the American Indians—living a healthy life in their native wilds, and under physical conditions which cause all bodily lesions to occasion far less constitutional or local disturbance than is the case with people living under the artificial conditions and the accumulated predisposition to disease which civilization entails—thus appear to suffer little, if at all, from this unnatural treatment, it seems to be otherwise with the French, on whom its effects have been watched by medical

observers more closely than it can have been on the savages in America. "Dr. Foville proves, by positive and numerous facts, that the most constant and the most frequent effects of this deformation, though only carried to a small degree, are headaches, deafnesses, cerebral congestions, meningitis, cerebritis, and epilepsy ; that idiocy or madness often terminates this series of evils ; and that the asylums for lunatics and imbeciles receive a large number of their inmates from among these unhappy people." * For this reason the French physicians have exerted all their influence, and with great success, to introduce a more rational system in the districts where the practice of compressing the heads of infants prevailed. †

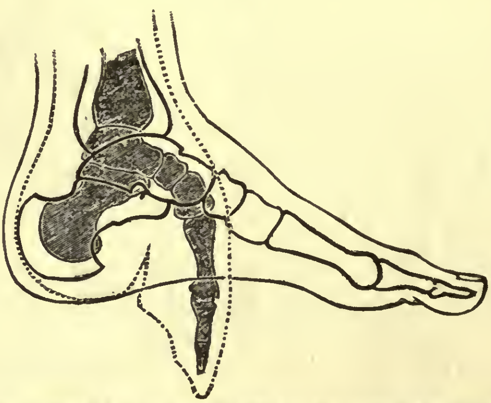

FIG. 14.—Section of Natural Foot with the Bones, and a corresponding section of a Chinese Deformed Foot. The outline of the latter is dotted, and the bones shaded.

We may now pass from the head to the extremities, but there will be little to say about the hands, for the artificial deformities practised upon those members are confined to chopping off one or more of the fingers, generally of the left hand, and usually not so much in obedience merely to fashion, as part of an initiatory ceremony, or an expiation or oblation to some superior, or to some departed person. Such practices are common among the American Indians, some tribes of Africans, the Australians, and Polynesians, especially those greatest of all slaves of ceremonial, the Fijians, where the amputation of fingers is demanded to appease an angry chieftain, or voluntarily performed as a token of affection on the occasion of the death of a relative.

But, *per contra*, the feet have suffered more, and altogether with more serious results to general health and comfort, from simple conformity to pernicious customs, than any other part of the body. And on this subject, instead of relating the unaccountable caprices of the savage, we have to speak only of people who have already advanced to a tolerably high grade of civilization, and to include all those who are at the present time foremost in the ranks of intellectual culture.

The most extreme instance of modification of the size and form of the foot, in obedience to fashion, is the well-known case of the Chinese women, not entirely confined to the highest classes, but in some districts pervading all grades of society alike. The deformity is produced by applying tight bandages

* Gosse, "Essai sur les Déformations artificielles du Crane, Annales d'Hygiene," 2 ser., tom. iv., p. 8.

† Ample references to the literature of artificially produced deformities of the cranium are given by Prof. Rolleston, in Greenwell's "British Barrows," 1877 (p. 596). To these may be added, Lenhossek, "Des Déformations artificielles du Crane," etc., Budapest, 1878, and Topinard, "Des Déformations ethniques du Crane," in the *Revue d'Anthropologie*, July 1879, p. 496.

round the feet of the girls when about five years old. The bandages are specially manufactured, Miss Norwood * tells us, and are about two inches wide and two yards long for the first year, five yards long for subsequent years. The end of the strip is laid on the inside of the foot at the instep, then carried over the toes, under the foot and round the heel, the toes being thus drawn toward and across the sole, while a bulge is produced in the instep and a deep indentation in the sole. Successive layers of bandage are wound round the foot until the strip is all used, and the end is then sewn tightly down. After a month the foot is put in hot water to soak some time; then the bandage is carefully unwound. Notwithstanding the powdered alum and other appliances that are used to prevent it, the surface of the foot is generally found to be ulcerated, and much of the skin and sometimes part of the flesh of the sole, and even one or two of the toes, may come off with the bandages, in which case the woman afterward feels repaid by the smallness and more delicate appearance of her feet. Each time the bandage is taken off, the foot is kneaded to make the joints more flexible, and is then bound up again as quickly as possible with a fresh bandage, which is drawn up more tightly. During the first year the pain is so intense that the sufferer can do nothing but lie and cry and moan. For about two years the foot aches continually, and is subject to a constant pain like the pricking of sharp needles. With continued rigorous binding it ultimately loses its sensibility, the muscles, nerves, and vessels are all wasted, the bones are altered in their relative position to one another, and the whole limb is reduced permanently to a stunted or atrophied condition.

Fig. 15.—Chinese Woman's Foot, from the inside A photograph by Dr. R. A. Jamieson.†

Fig. 16.—Sole of Chinese Woman's Foot.

The alterations produced in the form of the foot are—1, bending the four outer toes under the sole of the foot, so that the first or great toe alone retains its normal position, and a narrow point is produced in front; 2, compressing the roots of the toes and the heel downward and toward one another so as greatly to shorten the foot, and produce a deep transverse fold in the middle of the sole (Fig. 16). The whole has now the appearance of the hoof of some animal rather than a human foot, and affords a very inefficient organ of support, as the peculiar tottering gait of those possessing it clearly shows. When

* American missionary at Swatow, *Times*, September 2, 1880.

† Dr. Jamieson says, "The fashionable length for a Chinese lady's foot is between 3½ and 4 inches, but comparatively few parents succeed in arresting growth so completely. The above, taken from a woman in the middle station of life, measures almost exactly 5 inches."

once formed, the "golden lily," as the Chinese lady calls her delicate little foot, can never recover its original shape.

But strange as this custom seems to us, it is only a slight step in excess of what the majority of people in Europe subject themselves and their children to. From personal observation of a large number of feet of persons of all ages and of all classes of society in our own country, I do not hesitate to say that there are very few, if any, to be met with that do not, in some degree, bear evidence of having been subjected to a compressing influence more or less injurious. Let any one take the trouble to inquire into what a foot ought to be. For external form look at any of the antique models—the nude Hercules Farnese or the sandalled Apollo Belvidere; watch the beautiful freedom of motion in the wide-spreading toes of an infant; consider the wonderful mechanical contrivances for combining strength with mobility, firmness with flexibility; the numerous bones, articulations, ligaments; the great toe, with seven special muscles to give it that versatility of motion which was intended that it should possess—and then see what a miserable, stiffened, distorted thing is this same foot when it has been submitted for a number of years to the "improving" process to which our civilization condemns it. The toes all squeezed and flattened against each other; the great toe no longer in its normal position, but turned outward, pressing so upon the others that one or more of them frequently has to find room for itself either above or under its fellows; the joints all rigid, the muscles atrophied and powerless; the finely formed arch broken down; everything which is beautiful and excellent in the human foot destroyed—to say nothing of the more serious evils which so generally follow—corns, bunions, in-growing nails, and all their attendant miseries.

Now, the cause of this will be perfectly obvious to any one who compares the form of the natural foot with the last upon which the shoemaker makes the covering for that foot. This, in the words of the late Mr. Dowie, "is shaped in front like a wedge, the thick part or instep rising in a ridge from the centre or middle toe, instead of the great toe, as in the foot, slanting off to both sides from the middle, terminating at each side and in front like a wedge; that for the inside or great toe being similar to that for the outside or little toe, as if the human foot had the great toe in the middle and a little toe at each side, like the foot of a goose!"

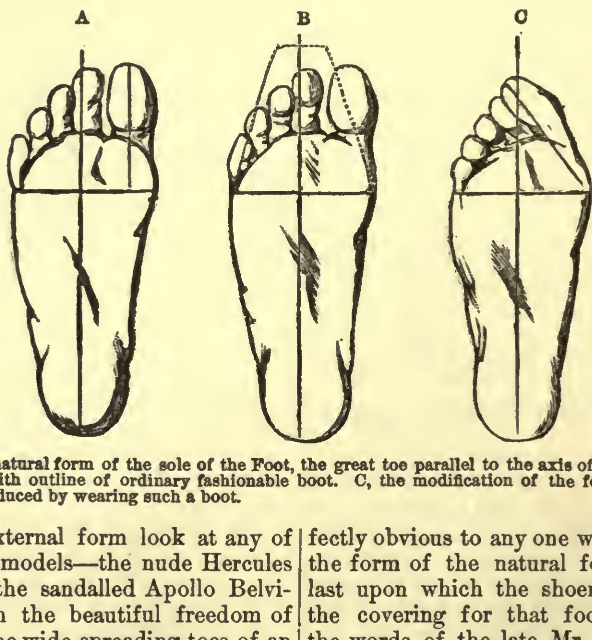

FIG. 17.—A, natural form of the sole of the Foot, the great toe parallel to the axis of the whole foot. B, the same, with outline of ordinary fashionable boot. C, the modification of the form of the foot, necessarily produced by wearing such a boot.

The great error in all boots and shoes made upon the system now in vogue in all parts of the civilized world lies in this method of construction upon a principle of bilateral symmetry. A straight line drawn along the sole from the middle of the toe to the heel will divide a fashionable boot into two equal and similar parts, a small allowance being made at the middle part, or "waist," for the difference between right and left foot. Whether the toe is made broad or narrow, it is always equally inclined at the sides toward the middle line; whereas in the foot there is no such symmetry. The first or inner toe is much larger than either of the others, and its direction is perfectly parallel with the long axis of the foot. The second toe may be a little longer than the first, as generally represented in Grecian art, but it is more frequently shorter;* the others rapidly decrease in size (Fig. 17, A). The modification which must have taken place in the form of the foot and direction of the toes before a boot of the ordinary form can be worn with any approach to ease is shown at Fig. 17, C. Often it will happen that the deformity has not advanced to so great an extent, but every one who has had the opportunity of examining many feet, especially among the poorer classes, must have met with many far worse. The two figured (Fig. 18), one (C) from a laboring man, the other (A and B) from a working woman, both patients at a London hospital, are very ordinary examples of the European artificial deformity of the foot, and afford good subjects for comparison with the Chinese foot (Fig. 16). It not unfrequently happens that the dislocation of the great toe is carried so far that it becomes placed almost at a right angle to the long axis of the foot, lying across the roots of the other toes.

A B C

Fig. 18.—English feet deformed by wearing improperly-shaped shoes. From nature.

In walking, and especially running, the action of the foot is as follows: The heel is first lifted from the ground, and the weight of the body gradually transferred through the middle to the anterior end of the foot, and the final

* It seems to be a very common idea with artists and sculptors, as well as anatomists, that the second toe ought to be longer than the first in a well-proportioned human foot, and so it is conventionally represented in art. The idea is derived from the Greek canon, which in its turn was copied from the Egyptian, and probably originally derived from the negro. It certainly does not represent what is most usual in our race and time. Among hundreds of bare and therefore undeformed feet of children I lately examined in Perthshire, I was not able to find one in which the second toe was the longest. As in all apes—in fact, in all other animals—the first toe is considerably shorter than the second, a long great toe is a specially human attribute, and instead of being despised by artists, it should be looked upon as a mark of elevation in the scale of organized beings.

push or impulse given with the great toe. It is necessary then that these parts should all be in a straight line with one another. Any deflection, especially of the great toe, from its proper direction, or any weakening of its bones, ligaments, or muscles, must be detrimental to the proper use of the foot in progression. Against this it will perhaps be urged that there are many fairly good walkers and runners among us whose great toes have been considerably changed from the normal position in consequence of wearing pointed boots while young. This may be perfectly true, but it is also well known that several persons, as the late Miss Biffin, and an artist familiar to all frequenters of the Antwerp picture gallery, have acquired considerable facility in the use of the brush, though possessing neither hands nor arms, the one painting only from the shoulder, and the other with the feet. The compensating power of nature is very wonderful, and when one part is absent or crippled, other means are found of doing its work, but always at a disadvantage as compared with those best fitted for the duty.

The loss of elasticity and motion in the joints of the foot, as well as the wrong direction acquired by the great toe, are in most persons seriously detrimental to free and easy progression, and can only be compensated for by a great expenditure of muscular power in other parts of the body, applied in a disadvantageous manner. The laboring men of this country, who from their childhood wear heavy, stiff, and badly-shaped boots, and in whom, consequently, the play of the ankle, feet, and toes is lost, have generally small and shapeless legs and wasted calves, and walk as if on stilts, with a swinging motion from the hips. Our infantry soldiers also suffer much in the same manner, the regulation boots in use in the service being exceedingly ill-adapted for the development of the feet. Much injury to the general health—the necessary consequence of any impediment to freedom of bodily exercise—must also be attributed to this cause. Since some of the leading shoemakers have ventured to deviate a little from the conventional shape, those persons who can afford to be specially fitted are better off as a rule than the majority of poorer people, who, although caring less for appearance, and being more dependent for their livelihood upon the physical welfare of their bodies, are obliged to wear ready-made shoes of the form that an inexorable custom has prescribed.

The changes that a foot has to undergo in order to adapt itself to the ordinary shape of a shoe could probably not be effected unless commenced at an early period, when it is young and capable of being gradually moulded into the required form.

The English mother or nurse who thrusts the tender feet of a young child into stiff, unyielding pointed shoes or boots, often regardless of the essential difference in form of right and left, at a time when freedom is especially needed for their proper growth and development, is the exact counterpart of the Chinook Indian woman, applying her bandages and boards to the opposite end of her baby's body, only with considerably less excuse ; for a distorted head apparently less affects health and comfort than cramped and misshapen feet, and was also esteemed of more vital importance to preferment in Chinook society. Any one who recollects the boots of the late Lord Palmerston will be reminded that a wide expanse of shoe leather is in this country, even during the prevalence of an opposite fashion, quite compatible with the attainment of the highest political and social eminence.

No sensible person can really suppose that there is anything in itself ugly, or even unsightly, in the form of a perfect human foot ; and yet all attempts to construct shoes upon its model are constantly met with the objection that something extremely inelegant must be the result. It will perhaps be a form to which the eye is not quite accustomed ; but there is no more trite observation than the arbitrary nature of fashion in her dealings with our outward appearance, and we all know how anything which has received her sanction is

for the time considered elegant and tasteful, though a few years later it may come to be looked upon as positively ridiculous. That our eye would soon get used to admire a different shape may be easily proved by any one who will for a short time wear shoes constructed upon a more correct principle, when the prevailing pointed shoes, suggestive of cramped and atrophied toes, become positively painful to look upon.

A glance at a series of pictures of costume at various periods of English history will show how fashion has changed at different times with respect to the coverings of the feet. The fact that the excessively pointed elongated toes of the time of Richard II., for instance, were superseded by the broad, round-toed, almost elephantine, but most comfortable shoes seen in the portraits of Henry VIII. and his contemporaries, shows that there is nothing in the former essential to the gratification of the æsthetic instincts of mankind. Each form was doubtless equally admired in the time of its prevalence.

It is not only leathern boots and shoes that are to blame for producing alterations in the form of the feet; even the stocking, comparatively soft and pliable as it is when made with pointed toes and similar form for both sides, must take its share. The continual, steady, though gentle pressure, keeps the toes squeezed together, and especially hinders the recovery of its proper form and mobility, when attempts at curing a misshapen foot are being made by wearing shoes of rational construction. Socks adapted to the different form of the two feet, or "rights and lefts," are occasionally to be met with at hosiers, and it would add greatly to comfort if they were more generally adopted. For some cases it is well to have them made with distinct toes like gloves. With such socks and properly constructed shoes, a much distorted foot, even of a middle-aged person, will recover its power and freedom of motion to a considerable extent.

Only one thing is needed to aggravate the evil effect of a pointed toe, and that is the absurdly high and narrow heel so often seen now on ladies' boots, which throws the whole foot, and in fact the whole body, into an unnatural position in walking, produces diseases well known to all surgeons in large practice, and makes the nearest approach yet effected by any European nation to the Chinese custom which we generally speak of with surprise and reprobation. And yet this fashion appears just now on the increase among people who boast of the highest civilization to which the world has yet attained.

FIG. 19.—Modern Parisian Shoe, copied from an advertisement in the *Queen* Newspaper. The nearest European representative of the Chinese deformity depicted in Fig. 15, p. 17.

The practice of turning out the toes, so much insisted on by dancing masters, when it becomes habitual, is a deformity. Although in standing in an easy position the whole limb may be rotated outward from the hip, so as to give a broader basis of support, in walking or running the hip, knee, ankle, and joints of the foot are simple hinges, and it is essential for the proper co-ordination of their actions that they should all work in the same plane, which can only be the case when the toes are pointed directly forward, and the feet nearly parallel to one another. Any deviation from this position must interfere with the true action of the foot when raising and propelling the body, as explained at p. 19. Turning out the toes is, moreover, a common cause of weak ankles, as it throws the weight of the body chiefly on the in-

side, instead of distributing it equally over all parts of the joint.

I must speak lastly of one of the most remarkable of all the artificial deformities produced by adherence to a conventional standard, in defiance of the dictates of nature and reason.

Of all parts of the body, the elastic and mobile walls of the chest would seem most to need preservation from external constriction, if they are to perform efficiently the important purposes for which their peculiar structure is specially designed. The skull is a solid case, with tolerably uniform walls, the capacity of which remains the same, whatever alteration is made in its shape. Pressure on one part is compensated for by dilatation elsewhere; the body is not so, it may be compared to a cylinder with a fixed length, determined by the vertebral column, and closed above and below by a framework of bone. Circular compression then must actually diminish the area which has to be occupied by some of the most important vital organs. Moreover, the framework of the chest is a most admirable and complex arrangement of numerous pieces of solid bone and elastic cartilage, jointed together in such a manner as to allow of expansion and contraction for the purposes of respiration—expansion and contraction which, if a function so essential to the preservation of life and health is to be performed in an efficient manner, should be perfectly free and capable of variation under different circumstances. So, indeed, it has been allowed to be in all parts of the world and in all ages, with one exception. It was reserved for mediæval civilized Europe to have invented the system of squeezing together, rendering immobile, and actually deforming, the most important part of the human frame; and the custom has been handed down to, and flourishes in, our day, notwithstanding all our professed admiration for the models of classical antiquity, and our awakened attention to the laws of health.

Fig. 20.
Torso of the Statue of Venus of Milo.

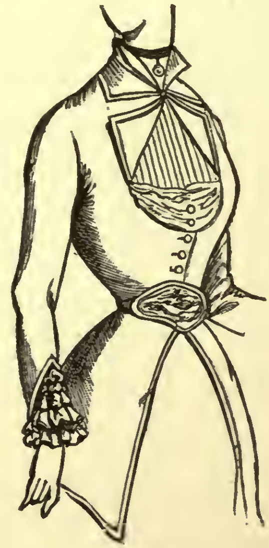

Fig. 21.
Paris Fashion, May, 1880.

It is only necessary to compare the above figures (Figs. 20 and 21)—one acknowledged by all the artistic and anatomical world to be a perfect example of the natural female form—to be convinced of the gravity of the structu-

ral changes that must have taken place in such a form before it could be reduced so far as to occupy the space shown in the second figure, an exact

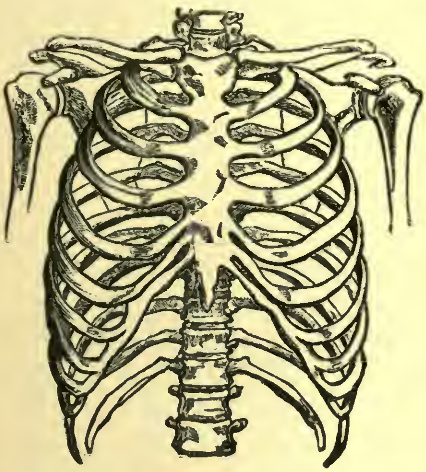

Fig. 22.—Normal form of the Skeleton of the Chest.

copy of one of the models now held up for imitation in the fashionable world. The actual changes that have taken place in the bony framework of the chest are seen by comparing the two figures on this page, the one showing the normal form, the other the result of long-continued tight-lacing. The alterations in the shape and position of the organs within need not be dwelt upon here; they and the evil effects arising from them are abundantly discussed in medical works. When it is considered that the organs which are affected are those by which the important functions of respiration, circulation, and digestion are carried on, as well as those essential to the proper development and healthy growth of future generations, it is no wonder that people suffer who have reduced themselves to live under such conditions.*

The true form of the human body is familiar to us, as just said, from classic models; it is familiar from the works of our greatest modern artists which adorn the Academy walls. It is, however, quite possible, or even probable, that some of us may think the present fashionable shape the more beautiful of the two. In such case it would be well to pause to consider whether we are sure that our judgment is sound on the subject. Let us remember that to the Australian the nose-peg is an admired ornament; that to the Thlinkeet, the Botocudo, and the Bongo negro, the lip dragged down by the heavy plug, and the ears distended by huge disks of wood, are things of beauty; that the Malay prefers teeth that are black to those of the most pearly whiteness; that the native American despises the form of a head not flattened down like a pancake, or elongated like a sugar-

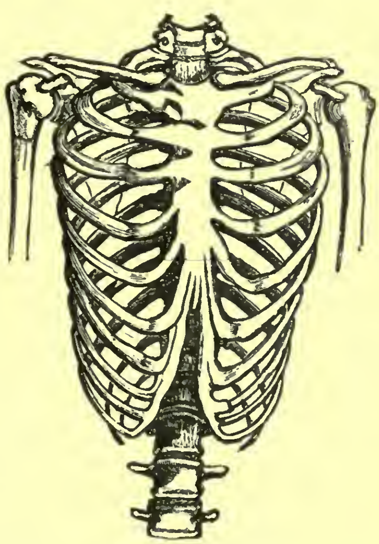

Fig. 23.—Skeleton of the Chest of a Woman, twenty-three years of age, deformed by tight-lacing, from Rüdinger's "Anatomie des Menschen." By no means an extreme case.

loaf; and then let us carefully ask ourselves whether we are sure that in leaving nature as a standard of the beautiful, and adopting a purely conventional one, we are not falling into an error ex-

* See, among many others, the section headed "Improprieties of Dress," in Dr. Gaillard Thomas's "Practical Treatise on the Diseases of Women" (5th Edit., 1881, p. 45), for convincing proofs (not mere general declamation) of the ill effects arising from tight-lacing.

actly similar to that of all these people whose tastes we are so ready to condemn.

The fact is that, in admiring such distorted forms as the constricted waist and symmetrically pointed foot, we are opposing our judgment to that of the Maker of our bodies ; we are neglecting the criterion afforded by nature ; we are departing from the highest standard of classical antiquity ; we are simply putting ourselves on a level in point of taste with those Australians, Botocudos, and Negroes. We are taking fashion, and nothing better, higher, or truer, for our guide ; and after the various examples which have now been brought forward, may we not well ask, with Shakespeare,

"SEEST THOU NOT WHAT A DEFORMED THIEF THIS FASHION IS ?"

MANNERS AND FASHION.

WHOEVER has studied the physiognomy of political meetings, cannot fail to have remarked a connection between democratic opinions and peculiarities of costume. At a Chartist demonstration, a lecture on Socialism, or a *soirée* of the Friends of Italy, there will be seen many among the audience, and a still larger ratio among the speakers, who get themselves up in a style more or less unusual. One gentleman on the platform divides his hair down the centre, instead of on one side ; another brushes it back off the forehead, in the fashion known as "bringing out the intellect ;" a third has so long forsworn the scissors, that his locks sweep his shoulders. A considerable sprinkling of mustaches may be observed ; here and there an imperial ; and occasionally some courageous breaker of conventions exhibits a full-grown beard.* This nonconformity in hair is countenanced by various nonconformities in dress, shown by others of the assemblage. Bare necks, shirt-collars *à la* Byron, waistcoats cut Quaker fashion, wonderfully shaggy great-coats, numerous oddities in form and color, destroy the monotony usual in crowds. Even those exhibiting no conspicuous peculiarity frequently indicate, by something in the pattern or make-up of their clothes, that they pay small regard to what their tailors tell them about the prevailing taste. And when the gathering breaks up, the varieties of head gear displayed—the number of caps, and the abundance of felt hats—suffice to prove that were the world at large like-minded, the black cylinders which tyrannize over us would soon be deposed.

The foreign correspondence of our daily press shows that this relationship between political discontent and the disregard of customs exists on the continent also. Red republicanism has always been distinguished by its hirsuteness. The authorities of Prussia, Austria, and Italy, alike recognize certain forms of hat as indicative of disaffection, and fulminate against them accordingly. In some places the wearer of a blouse runs a risk of being classed among the *suspects ;* and in others, he who would avoid the bureau of police, must beware how he goes out in any but the ordinary colors. Thus, democracy abroad, as at home, tends toward personal singularity.

Nor is this association of characteristics peculiar to modern times, or to reformers of the State. It has always existed ; and it has been manifested as much in religious agitations as in political ones. Along with dissent from the chief established opinions and arrangements, there has ever been some dissent from the customary social practices. The Puritans, disapproving of the long curls of the Cavaliers, as of their princi-

* This was written before mustaches and beards had become common.

ples, cut their own hair short, and so gained the name of "Roundheads." The marked religious nonconformity of the Quakers was accompanied by an equally-marked nonconformity of manners—in attire, in speech, in salutation. The early Moravians not only believed differently, but at the same time dressed differently, and lived differently, from their fellow Christians.

That the association between political independence and independence of personal conduct, is not a phenomenon of to-day only, we may see alike in the appearance of Franklin at the French court in plain clothes, and in the white hats worn by the last generation of Radicals. Originality of nature is sure to show itself in more ways than one. The mention of George Fox's suit of leather, or Pestalozzi's school name, "Harry Oddity," will at once suggest the remembrance that men who have in great things diverged from the beaten track, have frequently done so in small things likewise. Minor illustrations of this truth may be gathered in almost every circle. We believe that whoever will number up his reforming and rationalist acquaintances, will find among them more than the usual proportion of those who in dress or behavior exhibit some degree of what the world calls eccentricity.

If it be a fact that men of revolutionary aims in politics or religion are commonly revolutionists in custom also, it is not less a fact that those whose office it is to uphold established arrangements in State and Church are also those who most adhere to the social forms and observances bequeathed to us by past generations. Practices elsewhere extinct still linger about the headquarters of government. The monarch still gives assent to Acts of Parliament in the old French of the Normans; and Norman French terms are still used in law. Wigs, such as those we see depicted in old portraits, may yet be found on the heads of judges and barristers. The Beefeaters at the Tower wear the costume of Henry VII.'s bodyguard. The University dress of the present year varies but little from that worn soon after the Reformation. The claret-colored coat, knee-breeches, lace shirt frills, ruffles, white silk stockings, and buckled shoes, which once formed the usual attire of a gentleman, still survive as the court-dress. And it need scarcely be said that at *levées* and drawing-rooms, the ceremonies are prescribed with an exactness, and enforced with a rigor, not elsewhere to be found.

Can we consider these two series of coincidences as accidental and unmeaning? Must we not rather conclude that some necessary relationship obtains between them? Are there not such things as a constitutional conservatism, and a constitutional tendency to change? Is there not a class which clings to the old in all things; and another class so in love with progress as often to mistake novelty for improvement? Do we not find some men ready to bow to established authority of whatever kind; while others demand of every such authority its reason, and reject it if it fails to justify itself? And must not the minds thus contrasted tend to become respectively conformist and nonconformist, not only in politics and religion, but in other things? Submission, whether to a government, to the dogmas of ecclesiastics, or to that code of behavior which society at large has set up, is essentially of the same nature; and the sentiment which induces resistance to the despotism of rulers, civil or spiritual, likewise induces resistance to the despotism of the world's opinion. Look at them fundamentally, and all enactments, alike of the legislature, the consistory, and the saloon—all regulations, formal or virtual, have a common character: they are all limitations of men's freedom. "Do this—Refrain from that," are the blank formulas into which they may all be written; and in each case the understanding is that obedience will bring approbation here and paradise hereafter; while disobedience will entail imprisonment, or sending to Coventry, or eternal torments, as the case may be. And if restraints, however named, and through whatever apparatus of means exercised, are one in

their action upon men, it must happen that those who are patient under one kind of restraint are likely to be patient under another; and conversely, that those impatient of restraint in general will, on the average, tend to show their impatience in all directions.

That Law, Religion, and Manners are thus related—that their respective kinds of operation come under one generalization—that they have in certain contrasted characteristics of men a common support and a common danger—will, however, be most clearly seen on discovering that they have a common origin. Little as from present appearances we should suppose it, we shall yet find that at first, the control of religion, the control of laws, and the control of manners, were all one control. However incredible it may now seem, we believe it to be demonstrable that the rules of etiquette, the provisions of the statute-book, and the commands of the decalogue, have grown from the same root. If we go far enough back into the ages of primeval Fetishism, it becomes manifest that originally Deity, Chief, and Master of the ceremonies were identical. To make good these positions, and to show their bearing on what is to follow, it will be necessary here to traverse ground that is in part somewhat beaten, and at first sight irrelevant to our topic. We will pass over it as quickly as consists with the exigencies of the argument.

That the earliest social aggregations were ruled solely by the will of the strong man, few dispute. That from the strong man proceeded not only Monarchy, but the conception of a God, few admit; much as Carlyle and others have said in evidence of it. If, however, those who are unable to believe this will lay aside the ideas of God and man in which they have been educated, and study the aboriginal ideas of them, they will at least see some probability in the hypothesis. Let them remember that before experience had yet taught men to distinguish between the possible and the impossible; and while they were ready on the slightest suggestion to ascribe unknown powers to any object and make a fetish of it; their conceptions of humanity and its capacities were necessarily vague, and without specific limits. The man who by unusual strength, or cunning, achieved something that others had failed to achieve, or something which they did not understand, was considered by them as differing from themselves; and, as we see in the belief of some Polynesians that only their chiefs have souls, or in that of the ancient Peruvians that their nobles were divine by birth, the ascribed difference was apt to be not one of degree only, but one of kind.

Let them remember next, how gross were the notions of God, or rather of gods, prevalent during the same era and afterward—how concretely gods were conceived as men of specific aspects dressed in specific ways—how their names were literally "the strong," "the destroyer," "the powerful one," —how, according to the Scandinavian mythology, the "sacred duty of blood-revenge" was acted on by the gods themselves—and how they were not only human in their vindictiveness, their cruelty, and their quarrels with each other, but were supposed to have amours on earth, and to consume the viands placed on their altars. Add to which, that in various mythologies, Greek, Scandinavian, and others, the oldest beings are giants; that according to a traditional genealogy the gods, demi-gods, and in some cases men, are descended from these after the human fashion; and that while in the East we hear of sons of God who saw the daughters of men that they were fair, the Teutonic myths tell of unions between the sons of men and the daughters of the gods.

Let them remember, too, that at first the idea of death differed widely from that which we have; that there are still tribes who, on the decease of one of their number, attempt to make the corpse stand, and put food into his mouth; that the Peruvians had feasts at which the mummies of their dead Incas presided, when, as Prescott says,

they paid attention "to these insensible remains as if they were instinct with life;" that among the Fejees it is believed that every enemy has to be killed twice; that the Eastern Pagans give extension and figure to the soul, and attribute to it all the same substances, both solid and liquid, of which our bodies are composed; and that it is the custom among most barbarous races to bury food, weapons, and trinkets along with the dead body, under the manifest belief that it will presently need them.

Lastly, let them remember that the other world, as originally conceived, is simply some distant part of this world—some Elysian fields, some happy hunting-ground, accessible even to the living, and to which, after death, men travel in anticipation of a life analogous in general character to that which they led before. Then, co-ordinating these general facts—the ascription of unknown powers to chiefs and medicine men; the belief in deities having human forms, passions, and behavior; the imperfect comprehension of death as distinguished from life; and the proximity of the future abode to the present, both in position and character—let them reflect whether they do not almost unavoidably suggest the conclusion that the aboriginal god is the dead chief; the chief not dead in our sense, but gone away carrying with him food and weapons to some rumored region of plenty, some promised land, whither he had long intended to lead his followers, and whence he will presently return to fetch them.

This hypothesis once entertained, is seen to harmonize with all primitive ideas and practices. The sons of the deified chief reigning after him, it necessarily happens that all early kings are held descendants of the gods; and the fact that alike in Assyria, Egypt, among the Jews, Phœnicians, and ancient Britons, kings' names were formed out of the names of the gods, is fully explained. The genesis of Polytheism out of Fetishism, by the successive migrations of the race of god-kings to the other world—a genesis illustrated in the Greek mythology, alike by the precise genealogy of the deities, and by the specifically asserted apotheosis of the later ones—tends further to bear it out. It explains the fact that in the old creeds, as in the still extant creed of the Otaheitans, every family has its guardian spirit, who is supposed to be one of their departed relatives; and that they sacrifice to these as minor gods—a practice still pursued by the Chinese and even by the Russians. It is perfectly congruous with the Grecian myths concerning the wars of the Gods with the Titans and their final usurpation; and it similarly agrees with the fact that among the Teutonic gods proper was one Freir, who came among them by adoption, "but was born among the *Vanes*, a somewhat mysterious *other* dynasty of gods, who had been conquered and superseded by the stronger and more warlike Odin dynasty." It harmonizes, too, with the belief that there are different gods to different territories and nations, as there were different chiefs; that these gods contend for supremacy as chiefs do; and it gives meaning to the boast of neighboring tribes—"Our god is greater than your god." It is confirmed by the notion universally current in early times, that the gods come from this other abode, in which they commonly live, and appear among men—speak to them, help them, punish them. And remembering this, it becomes manifest that the prayers put up by primitive peoples to their gods for aid in battle, are meant literally—that their gods are expected to come back from the other kingdom they are reigning over, and once more fight the old enemies they had before warred against so implacably; and it needs but to name the Iliad, to remind every one how thoroughly they believed the expectation fulfilled.

All government, then, being originally that of the strong man who has become a fetish by some manifestation of superiority, there arises, at his death—his supposed departure on a long-projected expedition, in which he is accompanied by his slaves and concubines sacrificed at his tomb—there arises, then, the incipient division of religious

from political control, of civil rule from spiritual. His son becomes deputed chief during his absence; his authority is cited as that by which his son acts; his vengeance is invoked on all who disobey his son; and his commands, as previously known or as asserted by his son, become the germ of a moral code; a fact we shall the more clearly perceive if we remember that early moral codes inculcate mainly the virtues of the warrior, and the duty of exterminating some neighboring tribe whose existence is an offence to the deity.

From this point onward, these two kinds of authority, at first complicated together as those of principal and agent, become slowly more and more distinct. As experience accumulates, and ideas of causation grow more precise, kings lose their supernatural attributes; and, instead of God-king, become God-descended king, God-appointed king, the Lord's anointed, the vicegerent of heaven, ruler reigning by Divine right. The old theory, however, long clings to men in feeling, after it has disappeared in name; and "such divinity doth hedge a king," that even now, many, on first seeing one, feel a secret surprise at finding him an ordinary sample of humanity. The sacredness attaching to royalty attaches afterward to its appended institutions—to legislatures, to laws. Legal and illegal are synonymous with right and wrong; the authority of Parliament is held unlimited, and a lingering faith in governmental power continually generates unfounded hopes from its enactments. Political scepticism, however, having destroyed the divine *prestige* of royalty, goes on ever increasing, and promises ultimately to reduce the State to a purely secular institution, whose regulations are limited in their sphere, and have no other authority than the general will. Meanwhile, the religious control has been little by little separating itself from the civil, both in its essence and in its forms. While from the God-king of the savage have arisen in one direction, secular rulers who, age by age, have been losing the sacred attributes men ascribed to them; there has arisen in another direction, the conception of a deity, who, at first human in all things, has been gradually losing human materiality, human form, human passions, human modes of action; until now, anthropomorphism has become a reproach.

Along with this wide divergence in men's ideas of the divine and civil ruler has been taking place a corresponding divergence in the codes of conduct respectively proceeding from them. While the king was a deputy-god—a governor such as the Jews looked for in the Messiah—a governor considered, as the Czar still is, "Our God upon Earth"—it, of course, followed that his commands were the supreme rules. But as men ceased to believe in his supernatural origin and nature, his commands ceased to be the highest; and there arose a distinction between the regulations made by him and the regulations handed down from the old god-kings, who were rendered ever more sacred by time and the accumulation of myths. Hence came respectively, Law and Morality: the one growing ever more concrete, the other more abstract; the authority of the one ever on the decrease, that of the other ever on the increase; originally the same, but now placed daily in more marked antagonism.

Simultaneously there has been going on a separation of the institutions administering these two codes of conduct. While they were yet one, of course Church and State were one; the king was arch-priest, not nominally, but really—alike the giver of new commands and the chief interpreter of the old commands; and the deputy-priests coming out of his family were thus simply expounders of the dictates of their ancestry; at first as recollected, and afterwards as ascertained by professed interviews with them. This union—which still existed practically during the middle ages, when the authority of kings was mixed up with the authority of the pope, when there were bishop-rulers having all the powers of feudal lords, and when priests punished by penances—has been, step by step, becoming less close. Though monarchs

are still "defenders of the faith," and ecclesiastical chiefs, they are but nominally such. Though bishops still have civil power, it is not what they once had. Protestantism shook loose the bonds of union ; Dissent has long been busy in organizing a mechanism for the exercise of religious control, wholly independent of law ; in America, a separate organization for that purpose already exists ; and if anything is to be hoped from the Anti-State-Church Association—or, as it has been newly named, "The Society for the Liberation of Religion from State Patronage and Control"—we shall presently have a separate organization here also.

Thus alike in authority, in essence, and in form, political and spiritual rule have been ever more widely diverging from the same root. That increasing division of labor which marks the progress of society in other things, marks it also in this separation of government into civil and religious ; and if we observe how the morality which forms the substance of religions in general, is beginning to be purified from the associated creeds, we may anticipate that this division will be ultimately carried much farther.

Passing now to the third species of control—that of Manners—we shall find that this, too, while it had a common genesis with the others, has gradually come to have a distinct sphere and a special embodiment. Among early aggregations of men before yet social observances existed, the sole forms of courtesy known were the signs of submission to the strong man ; as the sole law was his will, and the sole religion the awe of his supposed supernaturalness. Originally, ceremonies were modes of behavior to the god-king. Our commonest titles have been derived from his names. And all salutations were primarily worship paid to him. Let us trace out these truths in detail, beginning with titles.

The fact already noticed, that the names of early kings among divers races are formed by the addition of certain syllables to the names of their gods—which certain syllables, like our *Mac* and *Fitz*, probably mean "son of," or "descended from"—at once gives meaning to the term *Father* as a divine title. And when we read, in Selden, that "the composition out of these names of Deities was not only proper to Kings : their Grandes and more honorable Subjects" (no doubt members of the royal race) "had sometimes the like ;" we see how the term *Father*, properly used by these also, and by their multiplying descendants, came to be a title used by the people in general. And it is significant as bearing on this point, that among the most barbarous nation in Europe, where belief in the divine nature of the ruler still lingers, *Father* in this higher sense is still a regal distinction. When, again, we remember how the divinity at first ascribed to kings was not a complimentary fiction but a supposed fact ; and how, further, under the Fetish philosophy the celestial bodies are believed to be personages who once lived among men ; we see that the appellations of oriental rulers, "Brother to the Sun," etc., were probably once expressive of a genuine belief ; and have simply, like many other things, continued in use after all meaning has gone out of them. We may infer, too, that the titles God, Lord, Divinity, were given to primitive rulers literally—that the *nostra divinitas* applied to the Roman emperors, and the various sacred designations that have been borne by monarchs, down to the still extant phrase, "Our Lord the King," are the dead and dying forms of what were once living facts. From these names, God, Father, Lord, Divinity, originally belonging to the God-king, and afterward to God and the king, the derivation of our commonest titles of respect is clearly traceable.

There is reason to think that these titles were originally proper names. Not only do we see among the Egyptians, where Pharaoh was synonymous with king, and among the Romans, where to be Cæsar meant to be Emperor, that the proper names of the greatest men were transferred to their successors, and so became class names ;

but in the Scandinavian mythology we may trace a human title of honor up to the proper name of a divine personage. In Anglo-Saxon *bealdor*, or *baldor*, means *Lord;* and Balder is the name of the favorite of Odin's sons—the gods who with him constitute the Teutonic Pantheon. How these names of honor became general is easily understood. The relatives of the primitive kings—the grandees described by Selden as having names formed on those of the gods, and shown by this to be members of the divine race—necessarily shared in the epithets, such as *Lord*, descriptive of superhuman relationships and nature. Their ever-multiplying offspring inheriting these, gradually rendered them comparatively common. And then they came to be applied to every man of power; partly from the fact that, in these early days when men conceived divinity simply as a stronger kind of humanity, great persons could be called by divine epithets with but little exaggeration; partly from the fact that the unusually potent were apt to be considered as unrecognized or illegitimate descendants of "the strong, the destroyer, the powerful one;" and partly, also, from compliment and the desire to propitiate.

Progressively as superstition diminished, this last became the sole cause. And if we remember that it is the nature of compliment, as we daily hear it, to attribute more than is due—that in the constantly widening application of "esquire," in the perpetual repetition of "your honor" by the fawning Irishman, and in the use of the name "gentleman" to any coalheaver or dustman by the lower classes of London, we have current examples of the depreciation of titles consequent on compliment—and that in barbarous times, when the wish to propitiate was stronger than now, this effect must have been greater; we shall see that there naturally arose an extensive misuse of all early distinctions. Hence the facts, that the Jews called Herod a god; that *Father*, in its higher sense, was a term used among them by servants to masters; that *Lord* was applicable to any person of worth and power. Hence, too, the fact that, in the later periods of the Roman Empire, every man saluted his neighbor as *Dominus* and *Rex*.

But it is in the titles of the middle ages, and in the growth of our modern ones out of them, that the process is most clearly seen. *Herr*, *Don*, *Signior*, *Seigneur*, *Señor*, were all originally names of rulers—of feudal lords. By the complimentary use of these names to all who could, on any pretence, be supposed to merit them, and by successive degradations of them from each step in the descent to a still lower one, they have come to be common forms of address. At first the phrase in which a serf accosted his despotic chief, *mein herr*, is now familiarly applied in Germany to ordinary people. The Spanish title *Don*, once proper to noblemen and gentlemen only, is now accorded to all classes. So, too, is it with *Signior* in Italy. *Seigneur* and *Monseigneur*, by contraction in *Sieur* and *Monsieur*, have produced the term of respect claimed by every Frenchman. And whether *Sire* be or be not a like contraction of *Signior*, it is clear that, as it was borne by sundry of the ancient feudal lords of France, who, as Selden says, "affected rather to bee stiled by the name of *Sire* than Baron, as *Le Sire de Montmorencie*, *Le Sire de Beauieu*, and the like, and as it has been commonly used to monarchs, our word *Sir*, which is derived from it, originally meant lord or king. Thus, too, is it with feminine titles. *Lady*, which, according to Horne Tooke, means *exalted*, and was at first given only to the few, is now given to all women of education. *Dame*, once an honorable name, to which, in old books, we find the epithets of "high-born" and "stately" affixed, has now, by repeated widenings of its application, become relatively a term of contempt. And if we trace the compound of this, *ma Dame*, through its contractions—*Madam*, *ma'am*, *mam*, *mum*, we find that the "Yes'm" of Sally to her mistress is originally equivalent to "Yes, my exalted," or "Yes, your highness." Throughout, therefore,

the genesis of words of honor has been the same. Just as with the Jews and with the Romans, has it been with the modern Europeans. Tracing these everyday names to their primitive significations of *lord* and *king*, and remembering that in aboriginal societies these were applied only to the gods and their descendants, we arrive at the conclusion that our familiar *Sir* and *Monsieur* are, in their primary and expanded meanings, terms of adoration.

Further to illustrate this gradual depreciation of titles, and to confirm the inference drawn, it may be well to notice in passing, that the oldest of them have, as might be expected, been depreciated to the greatest extent. Thus, *Master*—a word proved by its derivation and by the similiarity of the connate words in other languages (Fr., *maître* for *master;* Russ., *master;* Dan., *meester;* Ger., *meister*) to have been one of the earliest in use for expressing lordship—has now become applicable to children only, and under the modification of "Mister," to persons next above the laborer. Again, knighthood, the oldest kind of dignity, is also the lowest; and Knight Bachelor, which is the lowest order of knighthood, is more ancient than any other of the orders. Similarly, too, with the peerage, Baron is alike the earliest and least elevated of its divisions. This continual degradation of all names of honor has, from time to time, made it requisite to introduce new ones having that distinguishing effect which the originals had lost by generality of use; just as our habit of misapplying superlatives has, by gradually destroying their force, entailed the need for fresh ones. And if, within the last thousand years, this process has produced effects thus marked, we may readily conceive how, during previous thousands, the titles of gods and demi-gods came to be used to all persons exercising power; as they have since come to be used to persons of respectability.

If from names of honor we turn to phrases of honor, we find similar facts. The Oriental styles of address, applied to ordinary people—"I am your slave," "All I have is yours," "I am your sacrifice"—attribute to the individual spoken to the same greatness that *Monsieur* and *My Lord* do; they ascribe to him the character of an all-powerful ruler, so immeasurably superior to the speaker as to be his owner. So, likewise, with the Polish expressions of respect—"I throw myself under your feet," "I kiss your feet." In our now meaningless subscription to a formal letter—"Your most obedient servant,"—the same thing is visible. Nay, even in the familiar signature "Yours faithfully," the "yours," if interpreted as originally meant, is the expression of a slave to his master.

All these dead forms were once living embodiments of fact—were primarily the genuine indications of that submission to authority which they verbally assert; were afterward naturally used by the weak and cowardly to propitiate those above them; gradually grew to be considered the due of such; and, by a continually wider misuse, have lost their meanings, as *Sir* and *Master* have done. That like titles, they were in the beginning used only to the God-king, is indicated by the fact that, like titles, they were subsequently used in common to God and the king. Religious worship has ever largely consisted of professions of obedience, of being God's servants, of belonging to him to do what he will with. Like titles, therefore, these common phrases of honor had a devotional origin.

Perhaps, however, it is in the use of the word *you* as a singular pronoun that the popularizing of what were once supreme distinctions is most markedly illustrated. This speaking of a single individual in the plural, was originally an honor given only to the highest—was the reciprocal of the imperial "we" assumed by such. Yet now, by being applied to successively lower and lower classes, it has become all but universal. Only by one sect of Christians, and in a few secluded districts, is the primitive *thou* still used. And the *you*, in becoming common to all ranks has simultaneously lost every vestige of the honor once attaching to it.

But the genesis of Manners out of forms of allegiance and worship, is above all shown in men's modes of salutation. Note first the significance of the word. Among the Romans, the *salutatio* was a daily homage paid by clients and inferiors to superiors. This was alike the case with civilians and in the army. The very derivation of our word, therefore, is suggestive of submission. Passing to particular forms of obeisance (mark the word again), let us begin with the Eastern one of baring the feet. This was, primarily, a mark of reverence, alike to a god and a king. The act of Moses before the burning bush, and the practice of Mahometans, who are sworn on the Koran with their shoes off, exemplify the one employment of it; the custom of the Persians, who remove their shoes on entering the presence of their monarch, exemplifies the other. As usual, however, this homage, paid next to inferior rulers, has descended from grade to grade. In India, it is a common mark of respect; a polite man in Turkey always leaves his shoes at the door, while the lower orders of Turks never enter the presence of their superiors but in their stockings; and in Japan, this baring of the feet is an ordinary salutation of man to man.

Take another case. Selden, describing the ceremonies of the Romans, says: "For whereas it was usual either to kiss the Images of their Gods, or adoring them, to stand somewhat off before them, solemnly moving the right hand to the lips, and then, casting it as if they had cast kisses, to turne the body on the same hand (which was the right forme of Adoration), it grew also by custom, first that the emperors, being next to Deities, and by some accounted as Deities, had the like done to them in acknowledgment of their Greatness." If, now, we call to mind the awkward salute of a village schoolboy, made by putting his open hand up to his face and describing a semicircle with his forearm; and if we remember that the salute thus used as a form of reverence in country districts, is most likely a remnant of the feudal times; we shall see reason for thinking that our common wave of the hand to a friend across the street, represents what was primarily a devotional act.

Similarly have originated all forms of respect depending upon inclinations of the body. Entire prostration is the aboriginal sign of submission. The passage of Scripture, "Thou hast put all under his feet," and that other one, so suggestive in its anthropomorphism, "the Lord said unto my Lord, sit thou at my right hand, until I make thine enemies thy footstool," imply, what the Assyrian sculptures fully bear out, that it was the practice of the ancient god-kings of the East to trample upon the conquered. And when we bear in mind that there are existing savages who signify submission by placing the neck under the foot of the person submitted to, it becomes obvious that all prostration, especially when accompanied by kissing the foot, expressed a willingness to be trodden upon—was an attempt to mitigate wrath by saying, in signs, "Tread on me if you will." Remembering, further, that kissing the foot, as of the Pope, and of a saint's statue, still continues in Europe to be a mark of extreme reverence; that prostration to feudal lords was once general; and that its disappearance must have taken place, not abruptly, but by gradual modification into something else; we have ground for deriving from these deepest of humiliations all inclinations of respect; especially as the transition is traceable. The reverence of a Russian serf, who bends his head to the ground, and the salaam of the Hindoo, are abridged prostrations; a bow is a short salaam; a nod is a short bow.

Should any hesitate to admit this conclusion, then perhaps, on being reminded that the lowest of these obeisances are common where the submission is most abject; that among ourselves the profundity of the bow marks the amount of respect; and lastly, that the bow is even now used devotionally in our churches—by Catholics to their altars, and by Protestants at the name of Christ—they will see sufficient evi-

dence for thinking that this salutation also was originally worship.

The same may be said, too, of the curtsy, or courtesy, as it is otherwise written. Its derivation from *courtoisie*, courteousness, that is, behavior like that at court, at once shows that it was primarily the reverence paid to a monarch. And if we call to mind that falling upon the knees, or upon one knee, has been a common obeisance of subjects to rulers ; that in ancient manuscripts and tapestries, servants are depicted as assuming this attitude while offering the dishes to their masters at table ; and that this same attitude is assumed toward our own queen at every presentation ; we may infer, what the character of the curtsy itself suggests, that it is an abridged act of kneeling. As the word has been contracted from *courtoisie* into curtsy ; so the motion has been contracted from a placing of the knee on the floor, to a lowering of the knee toward the floor. Moreover, when we compare the curtsy of a lady with the awkward one a peasant girl makes, which, if continued, would bring her down on both knees, we may see in this a last remnant of that greater reverence required of serfs. And when, from considering that simple kneeling of the West, still represented by the curtsy, we pass Eastward, and note the attitude of the Mahomedan worshipper, who not only kneels but bows his head to the ground, we may infer that the curtsy, also, is an evanescent form of the aboriginal prostration.

In further evidence of this it may be remarked, that there has but recently disappeared from the salutations of men, an action having the same proximate derivation with the curtsy. That backward sweep of the foot with which the conventional stage-sailor accompanies his bow—a movement which prevailed generally in past generations, when "a bow and a scrape" went together, and which, within the memory of living persons, was made by boys to their schoolmaster, with the effect of wearing a hole in the floor—is pretty clearly a preliminary to going on one knee. A motion so ungainly could never have been intentionally introduced ; even if the artificial introduction of obeisances were possible. Hence we must regard it as the remnant of something antecedent ; and that this something antecedent was humiliating may be inferred from the phrase, "scraping an acquaintance ;" which, being used to denote the gaining of favor by obsequiousness, implies that the scrape was considered a mark of servility—that is, of *serf*-ility.

Consider, again, the uncovering of the head. Almost everywhere this has been a sign of reverence, alike in temples and before potentates ; and it yet preserves among us some of its original meaning. Whether it rains, hails, or shines, you must keep your head bare while speaking to the monarch ; and on no plea may you remain covered in a place of worship. As usual, however, this ceremony, at first a submission to gods and kings, has become in process of time a common civility. Once an acknowledgment of another's unlimited supremacy, the removal of the hat is now a salute accorded to very ordinary persons, and that uncovering, originally reserved for entrance into "the house of God," good manners now dictates on entrance into the house of a common laborer.

Standing, too, as a mark of respect, has undergone like extensions in its application. Shown, by the practice in our churches, to be intermediate between the humiliation signified by kneeling and the self-respect which sitting implies, and used at courts as a form of homage when more active demonstrations of it have been made, this posture is now employed in daily life to show consideration ; as seen alike in the attitude of a servant before a master, and in that rising which politeness prescribes on the entrance of a visitor.

Many other threads of evidence might have been woven into our argument. As, for example, the significant fact, that if we trace back our still existing law of primogeniture—if we consider it as displayed by Scottish clans, in which not only ownership but government devolved from the beginning on the eldest

son of the eldest—if we look farther back, and observe that the old titles of lordship, *Signor*, *Seigneur*, *Señor*, *Sire*, *Sieur*, all originally mean, senior, or elder—if we go eastward, and find that *Sheik* has a like derivation, and that the Oriental names for priests, as *Pir*, for instance, are literally interpreted *old man*—if we note in Hebrew records how primeval is the ascribed superiority of the first-born, how great the authority of elders, and how sacred the memory of patriarchs—and if, then, we remember that among divine titles are "Ancient of Days," and "Father of Gods and men;" we see how completely these facts harmonize with the hypothesis that the aboriginal god is the first man sufficiently great to become a tradition, the earliest whose power and deeds made him remembered; that hence antiquity unavoidably became associated with superiority, and age with nearness in blood to "the powerful one;" that so there naturally arose that domination of the eldest which characterizes all history, and that theory of human degeneracy which even yet survives.

We might further dwell on the facts, that *Lord* signifies high-born, or, as the same root gives a word meaning heaven, possibly heaven-born; that, before it became common, *Sir* or *Sire*, as well as *Father*, was the distinction of a priest; that *worship* originally worthship—a term of respect that has been used commonly, as well as to magistrates—is also our term for the act of attributing greatness or worth to the Deity; so that to ascribe worth-ship to a man is to worship him. We might make much of the evidence that all early governments are more or less distinctly theocratic; and that among ancient Eastern nations even the commonest forms and customs appear to have been influenced by religion. We might enfore our argument respecting the derivation of ceremonies, by tracing out the aboriginal obeisance made by putting dust on the head, which probably symbolizes putting the head in the dust; by affiliating the practice prevailing among certain tribes, of doing another honor by presenting him with a portion of hair torn from the head—an act which seems tantamount to saying, "I am your slave;" by investigating the Oriental custom of giving to a visitor any object he speaks of admiringly, which is pretty clearly a carrying out the compliment, "All I have is yours."

Without enlarging, however, on these and many minor facts, we venture to think that the evidence already assigned is sufficient to justify our position. Had the proofs been few or of one kind, little faith could have been placed in the inference. But numerous as they are, alike in the case of titles, in that of complimentary phrases, and in that of salutes—similar and simultaneous, too, as the process of depreciation has been in all of these; the evidences become strong by mutual confirmation. And when we recollect, also, that not only have the results of this process been visible in various nations and in all times, but that they are occurring among ourselves at the present moment, and that the causes assigned for previous depreciations may be seen daily working out other ones—when we recollect this, it becomes scarcely possible to doubt that the process has been as alleged; and that our ordinary words, acts, and phrases of civility were originally acknowledgments of submission to another's omnipotence.

Thus the general doctrine, that all kinds of government exercised over men were at first one government—that the political, the religious and the ceremonial forms of control are divergent branches of a general and once indivisible control—begins to look tenable. When, with the above facts fresh in mind, we read primitive records, and find that "there were giants in those days"—when we remember that in Eastern traditions Nimrod, among others, figures in all the characters of giant, king, and divinity—when we turn to the sculptures exhumed by Mr. Layard, and contemplating in them the effigies of kings driving over enemies, trampling on prisoners, and adored by

prostrate slaves, then observe how their actions correspond to the primitive names for the divinity, "the strong," "the destroyer," "the powerful one"—when we find that the earliest temples were also the residences of the kings—and when, lastly, we discover that among races of men still living, there are current superstitions analogous to those which old records and old buildings indicate; we begin to realize the probability of the hypothesis that has been set forth.

Going back, in imagination, to the remote era when men's theories of things were yet unformed; and conceiving to ourselves the conquering chief as dimly figured in ancient myths, and poems, and ruins; we may see that all rules of conduct whatever spring from his will. Alike legislator and judge, all quarrels among his subjects are decided by him; and his words become the Law. Awe of him is the incipient Religion; and his maxims furnish its first precepts. Submission is made to him in the forms he prescribes; and these give birth to Manners. From the first, time develops allegiance and the administration of justice; from the second, the worship of a being whose personality becomes ever more vague, and the inculcation of precepts ever more abstract; from the third, forms of honor and the rules of etiquette.

In conformity with the law of evolution of all organized bodies, that general functions are gradually separated into the special functions constituting them, there have grown up in the social organism for the better performance of the governmental office, an apparatus of law-courts, judges, and barristers; a national church, with its bishops and priests; and a system of caste, titles, and ceremonies, administered by society at large. By the first, overt aggressions are cognized and punished; by the second, the disposition to commit such aggressions is in some degree checked; by the third, those minor breaches of good conduct, which the others do not notice, are denounced and chastised. Law and Religion control behavior in its essentials; Manners control it in its details. For regulating those daily actions which are too numerous and too unimportant to be officially directed, there comes into play this subtler set of restraints. And when we consider what these restraints are—when we analyze the words, and phrases, and salutes employed, we see that in origin as in effect, the system is a setting up of temporary governments between all men who come in contact, for the purpose of better managing the intercourse between them.

From the proposition, that these several kinds of government are essentially one, both in genesis and function, may be deduced several important corollaries, directly bearing on our special topic.

Let us first notice, that there is not only a common origin and office for all forms of rule, but a common necessity for them. The aboriginal man, coming fresh from the killing of bears and from lying in ambush for his enemy, has, by the necessities of his condition, a nature requiring to be curbed in its every impulse. Alike in war and in the chase, his daily discipline has been that of sacrificing other creatures to his own needs and passions. His character, bequeathed to him by ancestors who led similar lives, is moulded by this discipline—is fitted to this existence. The unlimited selfishness, the love of inflicting pain, the bloodthirstiness, thus kept active, he brings with him into the social state. These dispositions put him in constant danger of conflict with his equally savage neighbor. In small things as in great, in words as in deeds, he is aggressive; and is hourly liable to the aggressions of others like natured. Only, therefore, by the most rigorous control exercised over all actions, can the primitive unions of men be maintained. There must be a ruler strong, remorseless, and of indomitable will; there must be a creed terrible in its threats to the disobedient; and there must be the most servile submission of all inferiors to superiors. The law must be cruel; the religion must be stern; the ceremonies must be strict.

The co-ordinate necessity for these several kinds of restraint might be largely illustrated from history were there space. Suffice it to point out, that where the civil power has been weak, the multiplication of thieves, assassins, and banditti, has indicated the approach of social dissolution; that when, from the corruptness of its ministry, religion has lost its influence, as it did just before the Flagellants appeared, the State has been endangered; and that the disregard of established social observances has ever been an accompaniment of political revolutions. Whoever doubts the necessity for a government of manners proportionate in strength to the co-existing political and religious governments, will be convinced on calling to mind that nntil recently even elaborate codes of behavior failed to keep gentlemen from quarrelling in the streets and fighting dnels in taverns; and on remembering further, that even now people exhibit at the doors of a theatre, where there is no ceremonial law to rule them, a degree of aggressiveness which would produce confusion if carried into social interconrse.

As might be expected, we find that, having a common origin and like general functions, these several controlling agencies act during each era with similar degrees of vigor. Under the Chinese despotism, stringent and multitudinous in its edicts and harsh in the enforcement of them, and associated with which there is an equally stern domestic despotism exercised by the eldest surviving male of the family, there exists a system of observances alike complicated and rigid. There is a tribunal of ceremonies. Previous to presentation at court, ambassadors pass many days in practising the required forms. Social intercourse is cumbered by endless compliments and obeisances. Class distinctions are strongly marked by badges. The chief regret on losing an only son is, that there will be no one to perform the sepulchral rites. And if there wants a definite measure of the respect paid to social ordinances, we have it in the torture to which ladies submit in having their feet crushed. In India, and indeed throughout the East, there exists a like connection between the pitiless tyranny of rulers, the dread terrors of immemorial creeds, and the rigid restraint of unchangeable customs; the caste regulations continue still unalterable; the fashions of clothes and furniture have remained the same for ages; suttees are so ancient as to be mentioned by Strabo and Diodorus Siculus; justice is still administered at the palace-gates as of old; in short, "every usage is a precept of religion and a maxim of jurisprudence."

A similar relationship of phenomena was exhibited in Europe during the Middle Ages. While all its governments were antocratic, while feudalism held sway, while the Church was unshorn of its power, while the criminal code was full of horrors and the hell of the popular creed full of terrors, the rules of behavior were both more numerous and more carefully conformed to than now. Differences of dress marked divisions of rank. Men were limited by law to a certain width of shoe-toes; and no one below a specified degree might wear a cloak less than so many inches long. The symbols on banners and shields were carefully attended to. Heraldry was an important branch of knowledge. Precedence was strictly insisted on. And those various salutes of which we now use the abridgments were gone through in full. Even during our own last century, with its corrupt House of Commons and little-curbed monarchs, we may mark a correspondence of social formalities. Gentlemen were still distinguished from lower classes by dress; people sacrificed themselves to inconvenient requirements — as powder, hooped petticoats, and towering head-dresses; and children addressed their parents as *Sir* and *Madam*.

A further corollary naturally following this last, and almost, indeed, forming part of it, is, that these several kinds of government decrease in stringency at the same rate. Simultaneously with the decline in the influence of priesthoods, and in the fear of eter-

nal torments—simultaneously with the mitigation of political tyranny, the growth of popular power, and the amelioration of criminal codes, has taken place that diminution of formalities and that fading of distinctive marks, now so observable. Looking at home, we may note that there is less attention to precedence than there used to be. No one in our day ends an interview with the phrase "your humble servant." The employment of the word *Sir*, once general in social intercourse, is at present considered bad breeding; and on the occasions calling for them it is held vulgar to use the words "Your Majesty," or "Your Royal Highness," more than once in a conversation. People no longer formally drink each other's healths; and even the taking wine with each other at dinner has ceased to be fashionable. The taking-off of hats between gentlemen has been gradually falling into disuse. Even when the hat is removed, it is no longer swept out at arm's length, but is simply lifted. Hence the remark made upon us by foreigners, that we take off our hats less than any other nation in Europe—a remark that should be coupled with the other, that we are the freest nation in Europe.

As already implied, this association of facts is not accidental. These titles of address and modes of salutation, bearing about them, as they all do, something of that servility which marks their origin, become distasteful in proportion as men become more independent themselves, and sympathize more with the independence of others. The feeling which makes the modern gentleman tell the laborer standing bareheaded before him to put on his hat—the feeling which gives us a dislike to those who cringe and fawn—the feeling which makes us alike assert our own dignity and respect that of others—the feeling which thus leads us more and more to discountenance all forms and names which confess inferiority and submission, is the same feeling which resists despotic power and inaugurates popular government, denies the authority of the Church, and establishes a right of private judgment.

A fourth fact, akin to the foregoing, is, that these several kinds of government not only decline together, but corrupt together. By the same process that a Court of Chancery becomes a place not for the administration of justice, but for the withholding of it—by the same process that a national church, from being an agency for moral control, comes to be merely a thing of formulas and tithes and bishoprics—by this same process do titles and ceremonies that once had a meaning and a power become empty forms.

Coats of arms which served to distinguish men in battle, now figure on the carriage panels of retired grocers. Once a badge of high military rank, the shoulder-knot has become, on the modern footman, a mark of servitude. The name Banneret, which once marked a partially-created Baron—a Baron who had passed his military "little go"—is now, under the modification of Baronet, applicable to any one favored by wealth or interest or party feeling. Knighthood has so far ceased to be an honor, that men now honor themselves by declining it. The military dignity *Escuyer* has, in the modern Esquire, become a wholly unmilitary affix. Not only do titles, and phrases, and salutes cease to fulfil their original functions, but the whole apparatus of social forms tends to become useless for its original purpose—the facilitation of social intercourse. Those most learned in ceremonies, and most precise in the observance of them, are not always the best behaved; as those deepest read in creeds and scriptures are not therefore the most religious; nor those who have the clearest notions of legality and illegality, the most honest. Just as lawyers are of all men the least noted for probity; as cathedral towns have a lower moral character than most others; so, if Swift is to be believed, courtiers are "the most insignificant race of people that the island can afford, and with the smallest tincture of good manners."

But perhaps it is in that class of social observances comprehended under the term Fashion, which we must here discuss parenthetically, that this process of corruption is seen with the greatest distinctness. As contrasted with Manners, which dictate our minor acts in relation to other persons, Fashion dictates our minor acts in relation to ourselves. While the one prescribes that part of our deportment which directly affects our neighbors ; the other prescribes that part of our deportment which is primarily personal, and in which our neighbors are concerned only as spectators. Thus distinguished as they are, however, the two have a common source. For while, as we have shown, Manners originate by imitation of the behavior pursued *toward* the great, Fashion originates by imitation *of* the behavior of the great. While the one has its derivation in the titles, phrases, and salutes used *to* those in power ; the other is derived from the habits and appearances exhibited *by* those in power.

The Carrib mother who squeezes her child's head into a shape like that of the chief ; the young savage who makes marks on himself similar to the scars carried by the warriors of his tribe (which is probably the origin of tattooing) ; the Highlander who adopts the plaid worn by the head of his clan ; the courtiers who affect grayness, or limp, or cover their necks, in imitation of their king ; and the people who ape the courtiers ; are alike acting under a kind of government connate with that of Manners, and, like it too, primarily beneficial. For, notwithstanding the numberless absurdities into which this copyism has led the people, from nose-rings to ear-rings, from painted faces to beauty-spots, from shaven heads to powdered wigs, from filed teeth and stained nails to bell-girdles, peaked shoes and breeches stuffed with bran—it must yet be concluded, that as the strong men, the successful men, the men of will, intelligence, and originality, who have got to the top, are, on the average, more likely to show judgment in their habits and tastes than the mass, the imitation of such is advantageous.

By and by, however, Fashion, corrupting like these other forms of rule, almost wholly ceases to be an imitation of the best, and becomes an imitation of quite other than the best. As those who take orders are not those having a special fitness for the priestly office, but those who see their way to a living by it ; as legislators and public functionaries do not become such by virtue of their political insight and power to rule, but by virtue of birth, acreage, and class influence ; so, the self-elected clique who set the fashion, gain this prerogative, not by their force of nature, their intellect, their higher worth or better taste, but gain it solely by their unchecked assumption. Among the initiated are to be found neither the noblest in rank, the chief in power, the best cultured, the most refined, nor those of greatest genius, wit, or beauty; and their reunions, so far from being superior to others, are noted for their inanity. Yet, by the example of these sham great, and not by that of the truly great, does society at large now regulate its goings and comings, its hours, its dress, its small usages. As a natural consequence, these have generally little or none of that suitableness which the theory of fashion implies they should have. But instead of a continual progress toward greater elegance and convenience, which might be expected to occur did people copy the ways of the really best or follow their own ideas of propriety, we have a reign of mere whim, of unreason, of change for the sake of change, of wanton oscillations from either extreme to the other—a reign of usages without meaning, times without fitness, dress without taste. And thus life *à la mode*, instead of being life conducted in the most rational manner, is life regulated by spendthrifts and idlres, milliners and tailors, dandies and silly women.

To these several corollaries—that the various orders of control exercised over men have a common origin and a common function, are called out by co-ordinate necessities and co-exist in like

stringency, decline together and corrupt together—it now only remains to add that they become needless together. Consequent as all kinds of government are upon the unfitness of the aboriginal man for social life ; and diminishing in coerciveness as they all do in proportion as this unfitness diminishes ; they must one and all come to an end as humanity acquires complete adaptation to its new conditions. That discipline of circumstances which has already wrought out such great changes in us, must go on eventually to work out yet greater ones. That daily curbing of the lower nature and culture of the higher, which out of cannibals and devil worshippers has evolved philanthropists, lovers of peace, and haters of superstition, cannot fail to evolve out of these, men as much superior to them as they are to their progenitors. The causes that have produced past modifications are still in action ; must continue in action as long as there exists any incongruity between man's desires and the requirements of the social state ; and must eventually make him organically fit for the social state. As it is now needless to forbid man-eating and Fetishism, so will it ultimately become needless to forbid murder, theft, and the minor offences of our criminal code. When human nature has grown into conformity with the moral law, there will need no judges and statute-books ; when it spontaneously takes the right course in all things, as in some things it does already, prospects of future reward or punishment will not be wanted as incentives ; and when fit behavior has become instinctive, there will need no code of ceremonies to say how behavior shall be regulated.

Thus, then, may be recognized the meaning, the naturalness, the necessity of those various eccentricities of reformers which we set out by describing. They are not accidental ; they are not mere personal caprices, as people are apt to suppose. On the contrary, they are inevitable results of the law of relationship above illustrated. That community of genesis, function, and decay which all forms of restraint exhibit, is simply the obverse of the fact at first pointed out, that they have in two sentiments of human nature a common preserver and a common destroyer. Awe of power originates and cherishes them all ; love of freedom undermines and periodically weakens them all. The one defends despotism and asserts the supremacy of laws, adheres to old creeds and supports ecclesiastical authority, pays respect to titles and conserves forms ; the other, putting rectitude above legality, achieves periodical instalments of political liberty, inaugurates Protestantism and works out its consequences, ignores the senseless dictates of Fashion and emancipates men from dead customs.

To the true reformer no institution is sacred, no belief above criticism. Everything shall conform itself to equity and reason ; nothing shall be saved by its prestige. Conceding to each man liberty to pursue his own ends and satisfy his own tastes, he demands for himself like liberty ; and consents to no restrictions on this, save those which other men's equal claims involve. No matter whether it be an ordinance of one man, or an ordinance of all men, if it trenches on his legitimate sphere of action, he denies its validity. The tyranny that would impose on him a particular style of dress and a set mode of behavior, he resists equally with the tyranny that would limit his buyings and sellings, or dictate his creed. Whether the regulation be formally made by a legislature, or informally made by society at large—whether the penalty for disobedience be imprisonment, or frowns and social ostracism, he sees to be a question of no moment. He will utter his belief notwithstanding the threatened punishment ; he will break conventions spite of the petty persecutions that will be visited on him. Show him that his actions are inimical to his fellow-men, and he will pause. Prove that he is disregarding their legitimate claims—that he is doing what in the nature of things must produce unhappiness, and he will alter his course. But until you do this—until you demonstrate that his proceedings

are essentially inconvenient or inelegant, essentially irrational, unjust, or ungenerous, he will persevere.

Some, indeed, argue that his conduct *is* unjust and ungenerous. They say that he has no right to annoy other people by his whims ; that the gentleman to whom his letter comes with no "Esq." appended to the address, and the lady whose evening party he enters with gloveless hands are vexed at what they consider his want of respect, or want of breeding ; that thus his eccentricities cannot be indulged save at the expense of his neighbor's feelings ; and that hence his nonconformity is in plain terms selfishness.

He answers that this position, if logically developed, would deprive men of all liberty whatever. Each must conform all his acts to the public taste, and not his own. The public taste on every point having been once ascertained, men's habits must thenceforth remain forever fixed ; seeing that no man can adopt other habits without sinning against the public taste, and giving people disagreeable feelings. Consequently, be it an era of pig-tails or high-heeled shoes, of starched ruffs or trunk-hose, all must continue to wear pig-tails, high-heeled shoes, starched ruffs, or trunk-hose to the crack of doom.

If it be still urged that he is not justified in breaking through others' forms that he may establish his own, and so sacrificing the wishes of many to the wishes of one, he replies that all religious and political changes might be negatived on like grounds. He asks whether Luther's sayings and doings were not extremely offensive to the mass of his contemporaries ; whether the resistance of Hampden was not disgusting to the time-servers around him ; whether every reformer has not shocked men's prejudices, and given immense displeasure by the opinions he uttered. The affirmative answer he follows up by demanding what right the reformer has, then, to utter these opinions ; whether he is not sacrificing the feelings of many to the feelings of one ; and so proves that, to be consistent, his antagonists must condemn not only all nonconformity in actions, but all nonconformity in thoughts.

His antagonists rejoin that *his* position, too, may be pushed to an absurdity. They argue that if a man may offend by the disregard of some forms, he may as legitimately do so by the disregard of all ; and they inquire—Why should he not go out to dinner in a dirty shirt, and with an unshorn chin ? Why should he not spit on the drawing-room carpet, and stretch his heels up to the mantel-shelf ?

The convention-breaker answers, that to ask this, implies a confounding of two widely-different classes of actions —the actions that are *essentially* displeasurable to those around, with the actions that are but *incidentally* displeasurable to them. He whose skin is so unclean as to offend the nostrils of his neighbors, or he who talks so loudly as to disturb a whole room, may be justly complained of, and rightly excluded by society from its assemblies. But he who presents himself in a surtout in place of a dress-coat, or in brown trousers instead of black, gives offence not to men's senses, or their innate tastes, but merely to their prejudices, their bigotry of convention. It cannot be said that his costume is less elegant or less intrinsically appropriate than the one prescribed ; seeing that a few hours earlier in the day it is admired. It is the implied rebellion, therefore, that annoys. How little the cause of quarrel has to do with the dress itself, is seen in the fact that a century ago black clothes would have been thought preposterous for hours of recreation, and that a few years hence some now forbidden style may be nearer the requirements of Fashion than the present one. Thus the reformer explains that it is not against the natural restraints, but against the artificial ones, that he protests ; and that manifestly the fire of sneers and angry glances which he has to bear, is poured upon him because he will not bow down to the idol which society has set up.

Should he be asked how we are to distinguish between conduct that is *absolutely* disagreeable to others, and con-

duct that is *relatively* so, he answers, that they will distinguish themselves, if men will let them. Actions intrinsically repugnant will ever be frowned upon, and must ever remain as exceptional as now. Actions not intrinsically repugnant will establish themselves as proper. No relaxation of customs will introduce the practice of going to a party in muddy boots, and with unwashed hands; for the dislike of dirt would continue were Fashion abolished to-morrow. That love of approbation which now makes people so solicitous to be *en règle* would still exist—would still make them careful of their personal appearance—would still induce them to seek admiration by making themselves ornamental—would still cause them to respect the natural laws of good behavior, as they now do the artificial ones. The change would simply be from a repulsive monotony to a picturesque variety. And if there be any regulations respecting which it is uncertain whether they are based on reality or on convention, experiment will soon decide, if due scope be allowed.

When at length the controversy comes round, as controversies often do, to the point whence it started, and the "party of order" repeat their charge against the rebel, that he is sacrificing the feelings of others to the gratification of his own wilfulness, he replies once for all that they cheat themselves by misstatements. He accuses them of being so despotic, that, not content with being masters over their own ways and habits, they would be masters over his also; and grumble because he will not let them. He merely asks the same freedom which they exercise; they, however, propose to regulate his course as well as their own—to cut and clip his mode of life into agreement with their approved pattern; and then charge him with wilfulness and selfishness, because he does not quietly submit! He warns them that he shall resist, nevertheless; and that he shall do so, not only for the assertion of his own independence, but for their good. He tells them that they are slaves, and know it not; that they are shackled, and kiss their chains; that they have lived all their days in prison, and complain at the walls being broken down. He says he must persevere, however, with a view to his own release; and in spite of their present expostulations, he prophesies that when they have recovered from the fright which the prospect of freedom produces, they will thank him for aiding in their emancipation.

Unamiable as seems this find-fault mood, offensive as is this defiant attitude, we must beware of overlooking the truths enunciated, in dislike of the advocacy. It is an unfortunate hinderance to all innovation, that in virtue of their very function, the innovators stand in a position of antagonism; and the disagreeable manners, and sayings, and doings, which this antagonism generates, are commonly associated with the doctrines promulgated. Quite forgetting that whether the thing attacked be good or bad, the combative spirit is necessarily repulsive; and quite forgetting that the toleration of abuses seems amiable merely from its passivity; the mass of men contract a bias against advanced views, and in favor of stationary ones, from intercourse with their respective adherents. "Conservatism," as Emerson says, "is debonnair and social; reform is individual and imperious." And this remains true, however vicious the system conserved, however righteous the reform to be effected. Nay, the indignation of the purists is usually extreme in proportion as the evils to be got rid of are great. The more urgent the required change, the more intemperate is the vehemence of its promoters. Let no one, then, confound with the principles of this social nonconformity the acerbity and the disagreeable self-assertion of those who first display it.

The most plausible objection raised against resistance to conventions, is grounded on its impolicy, considered even from the progressist's point of view. It is urged, by many of the more liberal and intelligent—usually those who have themselves shown some independence of behavior in earlier days—

that to rebel in these small matters is to destroy your own power of helping on reform in greater matters. "If you show yourself eccentric in manners or dress, the world," they say, "will not listen to you. You will be considered as crotchety, and impracticable. The opinions you express on important subjects, which might have been treated with respect had you conformed on minor points, will now inevitably be put down among your singularities; and thus, by dissenting in trifles, you disable yourself from spreading dissent in essentials."

Only noting, as we pass, that this is one of those anticipations which bring about their own fulfilment—that it is because most who disapprove these conventions do not show their disapproval, that the few who do show it look eccentric—and that did all act out their convictions, no such inference as the above would be drawn, and no such evil would result; noting this as we pass, we go on to reply that these social restraints, and forms, and requirements, are not small evils, but among the greatest. Estimate their sum total, and we doubt whether they would not exceed most others. Could we add up the trouble, the cost, the jealousies, vexations, misunderstandings, the loss of time and the loss of pleasure, which these conventions entail—could we clearly realize the extent to which we are all daily hampered by them, daily enslaved by them; we should perhaps come to the conclusion that the tyranny of Mrs. Grundy is worse than any other tyranny we suffer under. Let us look at a few of its hurtful results; beginning with those of minor importance.

It produces extravagance. The desire to be *comme il faut*, which underlies all conformities, whether of manners, dress, or styles of entertainment, is the desire which makes many a spendthrift and many a bankrupt. To "keep up appearances," to have a house in an approved quarter furnished in the latest taste, to give expensive dinners and crowded *soirées*, is an ambition forming the natural outcome of the conformist spirit. It is needless to enlarge on these follies; they have been satirized by hosts of writers, and in every drawing-room. All that here concerns us, is to point out that the respect for social observances, which men think so praiseworthy, has the same root with this effort to be fashionable in mode of living; and that, other things equal, the last cannot be diminished without the first being diminished also. If, now, we consider all that this extravagance entails—if we count up the robbed tradesmen, the stinted governesses, the ill-educated children, the fleeced relatives, who have to suffer from it—if we mark the anxiety and the many moral delinquencies which its perpetrators involve themselves in; we shall see that this regard for conventions is not quite so innocent as it looks.

Again, it decreases the amount of social intercourse. Passing over the reckless, and those who make a great display on speculation with the occasional result of getting on in the world to the exclusion of much better men, we come to the far larger class who, being prudent and honest enough not to exceed their means, and yet having a strong wish to be "respectable," are obliged to limit their entertainments to the smallest possible number; and that each of these may be turned to the greatest advantage in meeting the claims upon their hospitality, are induced to issue their invitations with little or no regard to the comfort or mutual fitness of their guests. A few inconveniently large assemblies, made up of people mostly strange to each other or but distantly acquainted, and having scarcely any tastes in common, are made to serve in place of many small parties of friends intimate enough to have some bond of thought and sympathy. Thus the quantity of intercourse is diminished, and the quality deteriorated. Because it is the custom to make costly preparations and provide costly refreshments; and because it entails both less expense and less trouble to do this for many persons on a few occasions than for few persons on many occasions, the reunions of our less wealthy classes are rendered alike infrequent and tedious.

Let it be further observed, that the existing formalities of social intercourse drive away many who most need its refining influence; and drive them into injurious habits and associations. Not a few men, and not the least sensible men either, give up in disgust this going out to stately dinners, and stiff evening-parties; and instead, seek society in clubs, and cigar-divans, and taverns. "I'm sick of this standing about in drawing-rooms, talking nonsense and trying to look happy," will answer one of them when taxed with his desertion. "Why should I any longer waste time and money, and temper? Once I was ready enough to rush home from the office to dress; I sported embroidered shirts, submitted to tight boots, and cared nothing for tailors' and haberdashers' bills. I know better now. My patience lasted a good while; for though I found each night pass stupidly, I always hoped the next would make amends. But I'm undeceived. Cab-hire and kid gloves cost more than any evening party pays for; or rather—it is worth the cost of them to avoid the party. No, no; I'll no more of it. Why should I pay five shillings a time for the privilege of being bored?"

If, now, we consider that this very common mood tends toward billiard-rooms, toward long sittings over cigars and brandy-and-water, toward Evans's and the Coal Hole, toward every place where amusement may be had; it becomes a question whether these precise observances which hamper our set meetings, have not to answer for much of the prevalent dissoluteness. Men must have excitements of some kind or other; and if debarred from higher ones will fall back upon lower. It is not that those who thus take to irregular habits are essentially those of low tastes. Often it is quite the reverse. Among half a dozen intimate friends, abandoning formalities and sitting at ease round the fire, none will enter with greater enjoyment into the highest kind of social intercourse—the genuine communion of thought and feeling; and if the circle includes women of intelligence and refinement, so much the greater is their pleasure. It is because they will no longer be choked with the mere dry husks of conversation which society offers them, that they fly its assemblies and seek those with whom they may have discourse that is at least real, though unpolished. The men who thus long for substantial mental sympathy, and will go where they can get it, are often, indeed, much better at the core than the men who are content with the inanities of gloved and scented party-goers—men who feel no need to come morally nearer to their fellow creatures than they can come while standing, tea-cup in hand, answering trifles with trifles; and who, by feeling no such need, prove themselves shallow-thoughted and cold-hearted.

It is true, that some who shun drawing-rooms do so from inability to bear the restraints prescribed by a genuine refinement, and that they would be greatly improved by being kept under these restraints. But it is not less true that, by adding to the legitimate restraints, which are based on convenience and a regard for others, a host of factitious restraints based only on convention, the refining discipline, which would else have been borne with benefit, is rendered unbearable, and so misses its end. Excess of government invariably defeats itself by driving away those to be governed. And if over all who desert its entertainments in disgust either at their emptiness or their formality, society thus loses its salutary influence—if such not only fail to receive that moral culture which the company of ladies, when rationally regulated, would give them, but, in default of other relaxation, are driven into habits and companionships which often end in gambling and drunkenness; must we not say that here, too, is an evil not to be passed over as insignificant?

Then consider what a blighting effect these multitudinous preparations and ceremonies have upon the pleasures they profess to subserve. Who, on calling to mind the occasions of his highest social enjoyments, does not find them to have been wholly informal, perhaps impromptu? How delightful a picnic

of friends, who forget all observances save those dictated by good nature! How pleasant the little unpretended gatherings of book-societies, and the like; or those purely accidental meetings of a few people well known to each other! Then, indeed, we may see that "a man sharpeneth the countenance of his friend." Cheeks flush, and eyes sparkle. The witty grow brilliant, and even the dull are excited into saying good things. There is an overflow of topics; and the right thought, and the right words to put it in, spring up unsought. Grave alternates with gay; now serious converse, and now jokes, anecdotes, and playful raillery. Every one's best nature is shown, every one's best feelings are in pleasureable activity; and, for the time, life seems well worth having.

Go now and dress for some half-past eight dinner, or some ten o'clock "at home;" and present yourself in spotless attire, with every hair arranged to perfection. How great the difference! The enjoyment seems in the inverse ratio of the preparation. These figures, got up with such finish and precision, appear but half alive. They have frozen each other by their primness; and your faculties feel the numbing effects of the atmosphere the moment you enter it. All those thoughts, so nimble and so apt awhile since, have disappeared—have suddenly acquired a preternatural power of eluding you. If you venture a remark to your neighbor, there comes a trite rejoinder, and there it ends. No subject you can hit upon outlives half a dozen sentences. Nothing that is said excites any real interest in you; and you feel that all you say is listened to with apathy. By some strange magic, things that usually give pleasure seem to have lost all charm.

You have a taste for art. Weary of frivolous talk, you turn to the table, and find that the book of engravings and the portfolio of photographs are as flat as the conversation. You are fond of music. Yet the singing, good as it is, you hear with utter indifference; and say "Thank you" with a sense of being a profound hypocrite. Wholly at ease though you could be, for your own part, you find that your sympathies will not let you. You see young gentlemen feeling whether their ties are properly adjusted, looking vacantly round, and considering what they shall do next. You see ladies sitting disconsolately, waiting for some one to speak to them, and wishing they had the wherewith to occupy their fingers. You see the hostess standing about the doorway, keeping a factitious smile on her face, and racking her brain to find the requisite nothings with which to greet her guests as they enter. You see numberless traits of weariness and embarrassment; and, if you have any fellow feeling, these cannot fail to produce a feeling of discomfort. The disorder is catching; and do what you will you cannot resist the general infection. You struggle against it; you make spasmodic efforts to be lively; but none of your sallies or your good stories do more than raise a simper or a forced laugh; intellect and feeling are alike asphyxiated. And when, at length, yielding to your disgust, you rush away, how great is the relief when you get into the fresh air, and see the stars! How you "Thank God, that's over!" and half resolve to avoid all such boredom for the future.

What, now, is the secret of this perpetual miscarriage and disappointment? Does not the fault lie with all these needless adjuncts — these elaborate dressings, these set forms, these expensive preparations, these many devices and arrangements that imply trouble and raise expectation? Who that has lived thirty years in the world has not discovered that Pleasure is coy; and must not be too directly pursued, but must be caught unawares? An air from a street-piano, heard while at work, will often gratify more than the choicest music played at a concert by the most accomplished musicians. A single good picture seen in a dealer's window, may give keener enjoyment than a whole exhibition gone through with catalogue and pencil. By the time we have got ready our elaborate apparatus by which to secure happiness, the hap-

piness is gone. It is too subtle to be contained in these receivers, garnished with compliments, and fenced round with etiquette. The more we multiply and complicate appliances, the more certain are we to drive it away.

The reason is patent enough. These higher emotions to which social intercourse ministers, are of extremely complex nature; they consequently depend for their production upon very numerous conditions; the more numerous the conditions, the greater the liability that one or other of them will be disturbed, and the emotions consequently prevented. It takes a considerable misfortune to destroy appetite; but cordial sympathy with those around may be extinguished by a look or a word. Hence it follows, that the more multiplied the *unnecessary* requirements with which social intercourse is surrounded, the less likely are its pleasures to be achieved. It is difficult enough to fulfil continuously all the *essentials* to a pleasurable communion with others; how much more difficult, then, must it be continuously to fulfil a host of *non-essentials* also! It is, indeed, impossible. The attempt inevitably ends in the sacrifice of the first to the last—the essentials to the non-essentials. What chance is there of getting any genuine response from the lady who is thinking of your stupidity in taking her in to dinner on the wrong arm? How are you likely to have agreeable converse with the gentleman who is fuming internally because he is not placed next to the hostess? Formalities, familiar as they may become, necessarily occupy attention—necessarily multiply the occasions for mistake, misunderstanding, and jealousy, on the part of one or other—necessarily distract all minds from the thoughts and feelings that should occupy them—necessarily, therefore, subvert those conditions under which only any sterling intercourse is to be had.

And this indeed is the fatal mischief which these conventions entail—a mischief to which every other is secondary. They destroy those highest of our pleasures which they profess to subserve. All institutions are alike in this, that however useful, and needful even, they originally were, they not only in the end cease to be so, but become detrimental. While humanity is growing, they continue fixed; daily get more mechanical and unvital; and by and by tend to strangle what they before preserved. It is not simply that they become corrupt and fail to act, they become obstructions. Old forms of government finally grow so oppressive, that they must be thrown off even at the risk of reigns of terror. Old creeds end in being dead formulas, which no longer aid but distort and arrest the general mind; while the State churches administering them, come to be instruments for subsidizing conservatism and repressing progress. Old schemes of education, incarnated in public schools and colleges, continue filling the heads of new generations with what has become relatively useless knowledge, and, by consequence, excluding knowledge which is useful. Not an organization of any kind—political, religious, literary, philanthropic—but what, by its ever-multiplying regulations, its accumulating wealth, its yearly addition of officers, and the creeping into it of patronage and party feeling, eventually loses its original spirit, and sinks into a mere lifeless mechanism, worked with a view to private ends—a mechanism which not merely fails of its first purpose, but is a positive hinderance to it.

Thus is it, too, with social usages. We read of the Chinese that they have "ponderous ceremonies transmitted from time immemorial," which make social intercourse a burden. The court forms prescribed by monarchs for their own exaltation, have, in all times and places, ended in consuming the comfort of their lives. And so the artificial observances of the dining-room and saloon, in proportion as they are many and strict, extinguish that agreeable communion which they were originally intended to secure. The dislike with which people commonly speak of society that is "formal," and "stiff," and "ceremonious," implies the general recognition of this fact; and this

recognition, logically developed, involves that all usages of behavior which are not based on natural requirements, are injurious. That these conventions defeat their own ends is no new assertion. Swift, criticizing the manners of his day, says, "Wise men are often more uneasy at the over-civility of these refiners than they could possibly be in the conversation of peasants and mechanics."

But it is not only in these details that the self-defeating action of our arrangements is traceable ; it is traceable in the very substance and nature of them. Our social intercourse, as commonly managed, is a mere semblance of the reality sought. What is it that we want ? Some sympathetic converse with our fellow-creatures ; some converse that shall not be mere dead words, but the vehicle of living thoughts and feelings—converse in which the eyes and the face shall speak, and the tones of the voice be full of meaning—converse which shall make us feel no longer alone, but shall draw us closer to another, and double our own emotions by adding another's to them. Who is there that has not, from time to time, felt how cold and flat is all this talk about politics and science, and the new books and the new men, and how a gennine ntterance of fellow-feeling ontweighs the whole of it ? Mark the words of Bacon : "For a crowd is not a company, and faces are but a gallery of pictures, and talk bnt a tinkling cymbal, where there is no love."

If this be true, then it is only after acquaintance has grown into intimacy, and intimacy has ripened into friendship, that the real communion which men need becomes possible. A rationally-formed circle must consist almost wholly of those on terms of familiarity and regard, with but one or two strangers. What folly, then, underlies the whole system of our grand dinners, our "at homes," our evening parties—assemblages made up of many who never met before, many others who just bow to each other, many others who though familiar feel mntual indifference, with just a few real friends lost in the general mass ! You need but look round at the artificial expressions of face, to see at once how it is. All have their disguises on ; and how can there be sympathy between masks ? No wonder that in private every one exclaims against the stupidity of these gatherings. No wonder that hostesses get them up rather because they must than because they wish. No wonder that the invited go less from the expectation of pleasure than from fear of giving offence. The whole thing is a gigantic mistake—an organized disappointment.

And then note, lastly, that in this case, as in all others, when an organization has become effete and inoperative for its legitimate purpose, it is employed for quite other ones—quite opposite ones. What is the usual plea put in for giving and attending these tedious assemblies ? "I admit that they are stupid and frivolons enough," replies every man to your criticisms ; "but then, you know, one must keep up one's connections." And conld you get from his wife a sincere answer, it would be, "Like you, I am sick of these frivolities ; but then, we must get our danghters married." The one knows that there is a profession to push, a practice to gain, a business to extend ; or parliamentary influence, or connty patronage, or votes, or office, to be got ; position, berths, favors, profit. The other's thoughts run upon husbands and settlements, wives and dowries. Worthless for their ostensible purpose of daily bringing human beings into pleasurable relations with each other, these cumbrous appliances of our social intercourse are now perseveringly kept in action with a view to the pecuniary and matrimonial results which they indirectly produce.

Who then shall say that the reform of our system of observances is unimportant ? When we see how this system induces fashionable extravagance, with its entailed bankruptcy and ruin —when we mark how greatly it limits the amount of social interconrse among the less wealthy classes—when we find that many who most need to be disciplined by mixing with the refined are

driven away by it, and led into dangerous and often fatal courses—when we count up the many minor evils it inflicts, the extra work which its costliness entails on all professional and mercantile men, the damage to public taste in dress and decoration by the setting up of its absurdities as standards for imitation, the injury to health indicated in the faces of its devotees at the close of the London season, the mortality of milliners and the like, which its sudden exigencies yearly involve; and when to all these we add its fatal sin, that it blights, withers up, and kills, that high enjoyment it professedly ministers to—that enjoyment which is a chief end of our hard struggling in life to obtain—shall we not conclude that to reform our system of etiquette and fashion, is an aim yielding to few in urgency?

There needs, then, a protestantism in social usages. Forms that have ceased to facilitate and have become obstructive—whether political, religious, or other—have ever to be swept away; and eventually are so swept away in all cases. Signs are not wanting that some change is at hand. A host of satirists, led on by Thackeray, have been for years engaged in bringing our sham-festivities, and our fashionable follies, into contempt; and in their candid moods, most men laugh at the frivolities with which they and the world in general are deluded. Ridicule has always been a revolutionary agent. That which is habitually assailed with sneers and sarcasms cannot long survive. Institutions that have lost their roots in men's respect and faith are doomed; and the day of their dissolution is not far off. The time is approaching, then, when our system of social observances must pass through some crisis, out of which it will come purified and comparatively simple.

How this crisis will be brought about, no one can with any certainty say. Whether by the continuance and increase of individual protests, or whether by the union of many persons for the practice and propagation of some better system, the future alone can decide. The influence of dissentients acting without co-operation, seems, under the present state of things, inadequate. Standing severally alone, and having no well-defined views; frowned on by conformists, and expostulated with even by those who secretly sympathize with them; subject to petty persecutions, and unable to trace any benefit produced by their example; they are apt, one by one, to give up their attempts as hopeless. The young convention-breaker eventually finds that he pays too heavily for his nonconformity. Hating, for example, everything that bears about it any remnant of servility, he determines, in the ardor of his independence, that he will uncover to no one. But what he means simply as a general protest, he finds that ladies interpret into a personal disrespect. Though he sees that, from the days of chivalry downward, these marks of supreme consideration paid to the other sex have been but a hypocritical counterpart to the actual subjection in which men have held them—a pretended submission to compensate for a real domination; and though he sees that when the true dignity of women is recognized, the mock dignities given to them will be abolished; yet he does not like to be thus misunderstood, and so hesitates in his practice.

In other cases, again, his courage fails him. Such of his unconventionalities as can be attributed only to eccentricity, he has no qualms about; for, on the whole, he feels rather complimented than otherwise in being considered a disregarder of public opinion. But when they are liable to be put down to ignorance, to ill-breeding, or to poverty, he becomes a coward. However clearly the recent innovation of eating some kinds of fish with knife and fork proves the fork-and-bread practice to have had little but caprice for its basis, yet he dares not wholly ignore that practice while fashion partially maintains it. Though he thinks that a silk handkerchief is quite as appropriate for drawing-room use as a white cambric one, he is not altogether at ease in acting out his opinion. Then,

too, he begins to perceive that his resistance to prescription brings round disadvantageous results which he had not calculated upon. He had expected that it would save him from a great deal of social intercourse of a frivolous kind —that it would offend the fools, but not the sensible people ; and so would serve as a self-acting test by which those worth knowing would be separated from those not worth knowing. But the fools prove to be so greatly in the majority that, by offending them, he closes against himself nearly all the avenues through which the sensible people are to be reached. Thus he finds that his nonconformity is frequently misinterpreted ; that there are but few directions in which he dares to carry it consistently out ; that the annoyances and disadvantages which it brings upon him are greater than he anticipated ; and that the chances of his doing any good are very remote. Hence he gradually loses resolution, and lapses, step by step, into the ordinary routine of observances.

Abortive as individual protests thus generally turn out, it may possibly be that nothing effectual will be done until there arises some organized resistance to this invisible despotism, by which our modes and habits are dictated. It may happen, that the government of Manners and Fashion will be rendered less tyrannical, as the political and religious governments have been, by some antagonistic union. Alike in Church and State, men's first emancipations from excess of restriction were achieved by numbers, bound together by a common creed or a common political faith. What remained undone while there were but individual schismatics or rebels, was effected when there came to be many acting in concert. It is tolerably clear that these earliest instalments of freedom could not have been obtained in any other way ; for so long as the feeling of personal independence was weak and the rule strong, there could never have been a sufficient number of separate dissentients to produce the desired results. Only in these later times, during which the secular and spiritual controls have been growing less coercive, and the tendency toward individual liberty greater, has it become possible for smaller and smaller sects and parties to fight against established creeds and laws ; until now men may safely stand even alone in their antagonism.

The failure of individual nonconformity to customs, as above illustrated, suggests that an analogous series of changes may have to be gone through in this case also. It is true that the *lex non scripta* differs from the *lex scripta* in this, that, being unwritten, it is more readily altered ; and that it has, from time to time, been quietly ameliorated. Nevertheless, we shall find that the analogy holds substantially good. For in this case, as in the others, the essential revolution is not the substituting of any one set of restraints for any other, but the limiting or abolishing the authority which prescribes restraints. Just as the fundamental change inaugurated by the Reformation, was not a superseding of one creed by another, but an ignoring of the arbiter who before dictated creeds —just as the fundamental change which democracy long ago commenced, was not from this particular law to that, but from the despotism of one to the freedom of all ; so, the parallel change yet to be wrought out in this supplementary government of which we are treating, is not the replacing of absurd usages by sensible ones, but the dethronement of that secret, irresponsible power which now imposes our usages, and the assertion of the right of all individuals to choose their own usages. In rules of living, a West-end clique is our Pope ; and we are all papists, with but a mere sprinkling of heretics. On all who decisively rebel, comes down the penalty of excommunication, with its long catalogue of disagreeable and, indeed, serious consequences.

The liberty of the subject asserted in our constitution, and ever on the increase, has yet to be wrested from this subtler tyranny. The right of private judgment, which our ancestors wrung from the church, remains to be claimed

from this dictator of our habits. Or, as before said, to free us from these idolatries and superstitious conformities, there has still to come a protestantism in social usages. Parallel, therefore, as is the change to be wrought out, it seems not improbable that it may be wrought out in an analogous way. That influence which solitary dissentients fail to gain, and that perseverance which they lack, may come into existence when they unite. That persecution which the world now visits upon them from mistaking their nonconformity for ignorance or disrespect, may diminish when it is seen to result from principle. The penalty which exclusion now entails may disappear when they become numerous enough to form visiting circles of their own. And when a successful stand has been made, and the brunt of the opposition has passed, that large amount of secret dislike to our observances which now pervades society, may manifest itself with sufficient power to effect the desired emancipation.

Whether such will be the process, time alone can decide. That community of origin, growth, supremacy, and decadence, which we have found among all kinds of government, suggests a community in modes of change also. On the other hand, Nature often performs substantially similar operations, in ways apparently different. Hence these details can never be foretold.

Meanwhile, let us glance at the conclusions that have been reached. On the one side, government, originally one, and afterward subdivided for the better fulfilment of its function, must be considered as having ever been, in all its branches — political, religious, and ceremonial — beneficial; and, indeed, absolutely necessary. On the other side, government, under all its forms, must be regarded as subserving a temporary office, made needful by the unfitness of aboriginal humanity for social life; and the successive diminutions of its coerciveness in State, in Church, and in Custom, must be looked upon as steps toward its final disappearance. To complete the conception, there requires to be borne in mind the third fact, that the genesis, the maintenance, and the decline of all governments, however named, are alike brought about by the humanity to be controlled; from which may be drawn the inference that, on the average, restrictions of every kind cannot last much longer than they are wanted, and cannot be destroyed much faster than they ought to be.

Society, in all its developments, undergoes the process of exuviation. These old forms which it successively throws off, have all been once vitally united with it—have severally served as the protective envelopes within which a higher humanity was being evolved. They are cast aside only when they become hinderances—only when some inner and better envelope has been formed; and they bequeath to us all that there was in them good. The periodical abolitions of tyrannical laws have left the administration of justice not only uninjured, but purified. Dead and buried creeds have not carried with them the essential morality they contained, which still exists, uncontaminated by the sloughs of superstition. And all that there is of justice and kindness and beauty, embodied in our cumbrous forms of etiquette, will live perennially when the forms themselves have been forgotten.

THE END.

CONTENTS.

Beacon Lights of Science

MIND AND BODY

THE THEORIES OF THEIR RELATION

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CHAPTER I.

QUESTION STATED.

MANY persons, mocking, ask, What has mind to do with brain substance, white and gray? Can any facts or laws regarding the spirit of man be gained through a scrutiny of nerve fibres and nerve cells?

The question, whatever may be insinuated in putting it, is highly relevant, and raises great issues.

The conceivable answers are various:

First. Granting mind and body to be in our present life inseparable, yet the two might be supposed to have their modes of existence altogether distinct, the one being wholly unaffected by the other. Consequently each would have to be studied in its own way, and for its own sake alone. On this supposition, the study of brain matter might be interesting as physiology and for application to medicine and surgery, but would be quite beyond the province of the mental philosopher.

Although no intrinsic improbability attaches to this supposition, it is scarcely in accordance with what we find in the usual course of things. There is no example of two agents so closely united as mind and body, without some mutual interference or adaptation. Still, the union of our incorporeal and corporeal parts is a case quite peculiar, not to say unique; and we are not entitled to pronounce beforehand as to the behavior of two such agents in respect of each other.

Secondly. There might be certain mental functions of a *lower* kind, partially dependent upon the material organization, while the highest functions might be of a purely spiritual nature, in no way governed by physical conditions. For receiving impressions, in the first instance, we need the external senses; we are dependent on the constitution and working of the eye, the ear, the organ of touch, and so on; yet the deeper processes named memory, reason, imagination—may be pure spirit, beyond and apart from all material processes,

In such a case, the inquirer into mind would do well to study the mechanism of the senses; but, for the purpose he has in view, it would be needless to go farther.

Thirdly. There may be an intimate relation and dependence of mind and body all through, every mental act having a concurrent bodily change; yet the two modes of operation may be so different as to throw no light on each other. No great laws may be traceable on either side, or the laws may be couched in such heterogeneous terms that we can make no comparison of the two. A pleasure and a nervous current are found to arise simultaneously; but the concurrence (we may suppose) signifies nothing, suggests nothing. There is something to be gained by connecting pleasure with a repast, a concert, or a holiday; but the mention of nerve currents gives no information of a practical kind, and does not add to our knowledge of the laws of pleasure.

Fourthly. While allowing it to be possible that a thorough understanding of the brain would contribute to a knowledge of the mind, one might deny that anything yet known, or in immediate prospect of being known, is of value in that way. Thus the obtrusion of physiology at the present stage would be superfluous and impotent.

Fifthly. The position may be taken that a knowledge of the bodily workings has already improved our knowledge of the mental workings, and, as we continue our researches, will do so more and more.

Which of these suppositions is the truth could be seen only after examining the actual state of the case. On a theme so peculiar and so difficult, the only surmise admissible beforehand would be, that the two distinct natures could not subsist in their present intimate alliance, and yet be wholly indifferent to one another; that they would be found to have some kind of mutual co-operation; that the ongoings of the one would be often a clew to the ongoings of the other.

The form of the interrogation that the foregoing remarks are designed to answer, may be objected to as purely rhetorical and in some measure unfair. If the matter of the brain were the only substance that mental functions could be attributed to, all the knowledge that we possess of that organ might not avail us much in laying down laws of connection between mind and body. But such is not the fact. The entire bodily system, though in varying degrees, is in intimate alliance with mental functions. To confine our study to the nervous substance would be to misrepresent the connection; and the knowledge of that substance, however complete, would not suffice for the solution of the problem. Looking at a child's cut finger, we can divine its feelings; if we see a smiling countenance, we know something of the mental tone of the individual.

It might seem that we must yet be a long way from understanding an organ so minute and so complicated as the brain. If we were to confine ourselves to the one mode of post-mortem dissection, we should probably attain but a small measure of success. But another road is open. We can begin at the outworks, at the organs of sense and motion, with which the nervous system communicates; we can study their operations during life, as well as examine their intimate structure; we can experimentally vary all the circumstances of their operation; we can find how they act upon the brain, and how the brain reacts up them. Using all this knowledge as a key, we may possibly unlock the secrets of the anatomical structure; we may compel the cells and fibres to disclose their meaning and purpose.

CHAPTER II.

CONNECTION OF MIND AND BODY.

The facts showing that the connection of mind and body is not occasional or partial, but thoroughgoing and complete, are such as the following:

In the first place, it has been noted in all ages and countries that the feelings possess a natural language or expression. So constant are the appearances characterizing the different classes of emotions, that we regard them as a part of the emotions themselves.

The smile of joy the puckered features in pain, the stare of astonishment, the quivering of fear, the tones and glance of tenderness, the frown of anger, are united in seemingly inseparable association with the states of feeling that they indicate. If a feeling arises without its appropriate sign or accompaniment, we account for the failure either by voluntary suppression or by the faintness of the excitement, there being a certain degree or intensity requisite to affect the bodily organs.*

On this uniformity of connection between feelings and their bodily expression depends our knowledge of each other's mind and character. When any one is pleased, or pained, or loving, or angry, unless there is purposed concealment, we are aware of the fact, and can even estimate in any given case the degree of the feeling.

From a variety of causes, we are deeply interested in the outward display of emotion. The face of inanimate nature does not arrest our attention so strongly as the deportment of our fellow-beings; in truth, the highest

* The following remarks of Mr. Darwin are in point: Most of our emotions [he should have said all] are so closely connected with their expression, that they hardly exist if the body remains passive. A man, for instance, may know that his life is in the extremest peril, and may strongly desire to save it; yet, as Louis XVI. said, when surrounded by a fierce mob, "Am I afraid? feel my pulse." So a man may intensely hate another; but until his bodily frame is affected, he cannot be said to be enraged. ("Expression," p 239.)

To the like effect Dr. Maudsley observes: "The special muscular action is not merely the exponent of the passion, but truly an essential part of it. If we try, while the features are fixed in the expression of one passion, to call up in the mind a different one, we shall find it impossible to do so." ("Body and Mind," p. 30.)

attraction of natural objects is imparted to them by a fictitious process of investing them with human feelings. The sun and the moon, the winds and the rivers, are less engaging when viewed as mere physical agencies, than when they are supposed to operate by human motives and purposes, loves and hates.

The interest of the human presence, in all its various workings, regarded as symptomatic of mental processes, is laid hold of and heightened in the fine art of cultivated nations. To the painter, the sculptor, and the poet, every feeling has its appropriate manifestation. Not merely are the grosser forms of feeling thus linked with material adjuncts; in the artist's view, the loftiest, the noblest, the holiest of the human emotions have their marked and inseparable attitude and deportment. In the artistic conceptions of the Middle Ages, more especially, the most divine attributes of the immaterial soul had their counterpart in the material body: the martyr, the saint, the Blessed Virgin, the Saviour himself, manifested their glorious nature by the sympathetic movements of the mortal framework. So far as concerns the entire compass of our feelings or emotions, it is the universal testimony of mankind that these have no independent spiritual subsistence, but are in every case embodied in our fleshly form.

This very strong and patent fact has been usually kept out of view in the multifarious discussions respecting the immaterial soul. Apparent as it is to the vulgar, and intently studied as it has been by the sculptor, the painter, and the poet, it has been disregarded both by metaphysicians and by theologians when engaged in settling the boundaries of mind and body.

A second class of proofs of the intimate connection between mind and body is furnished by the effects of bodily changes on mental states, and of mental changes on bodily states.

The embarrassment in dealing with this group of facts is their number. I shall commence with a few of the ordinary and recognized instances, and then refer to the comprehensive generalities arrived at by physiologists.

As to the influence of bodily changes on mental states, we have such facts as the dependence of our feelings and moods upon hunger, repletion, the state of the stomach, fatigue and rest, pure and impure air, cold and warmth, stimulants and drugs, bodily injuries, disease, sleep, advancing years. These influences extend not merely to the grosser modes of feeling, and to such familiar exhibitions as after-dinner oratory, but also to the highest emotions of the mind—love, anger, æsthetic feeling, and moral sensibility. "Health keeps an atheist in the dark." Bodily affliction is often the cause of a total change in the moral nature.

The bodily routine of our daily life is the counterpart of the mental routine. A healthy man wakens in the morning with a flush of spirits and energy; his first meal confirms and reinforces the state. The mental powers and susceptibilities are then at their maximum; as the nutrition is used up in the system, they gradually fade, but may be renewed once and again by refreshment and brief remission of toil. Toward the end of the day lassitude sets in, and fades into the deep unconsciousness of healthy sleep.

Since the intellectual faculties appear to be most removed from the effect of physical agencies, I will quote a few facts, showing that in reality they have no exemption from the general rule. The memory rises and falls with the bodily condition, being vigorous in our fresh moments, and feeble when we are fatigued or exhausted. It is related by Sir Henry Holland that on one occasion he descended, on the same day, two deep mines in the Hartz Mountains, remaining some hours in each. In the second mine he was so exhausted with inanition and fatigue that his memory utterly failed him; he could not recollect a single word of German. The power came back after taking food and wine. Old age notoriously impairs the memory in ninety-nine men out of a hundred.

In the delirium of fever the sense of hearing sometimes becomes extraordinarily acute. Among the premonitory symptoms of brain disease has been noticed an unusual delicacy of the sense of sight; the physician suspects that there is already congestion of blood, to be followed perhaps by effusion.

Any person fancying that trains of thinking have little dependence on the bodily organs should also reflect on such facts as these. When walking, or engaged in any bodily occupation, if an interesting idea occurs to the mind, or is imparted to us by another person, we suddenly stop, and remain at rest, until the excitement has subsided. Again, our cogitations usually induce some bodily attitudes (laid hold of by artists as the outward expression of thought) as well as movements; and if anything occurs to disturb these, the current of thinking is suspended or diverted. Why should sleep suspend all thought, except the incoherency of dreaming (absent in perfect sleep), if a certain condition of the bodily powers were not indispensable to the intellectual functions?

Much stress has been laid upon certain apparent exceptions to these sweeping rules. Under bodily weakness, abstinence, fatigue, disease, and old age, individuals occasionally manifest high mental energy and elation, and great intellectual power. The lives of martyrs and heroes are replete with such exceptional vigor. If the inference be that the mind, notwithstanding a large amount of dependence on the body, is still, to a certain degree, self-supporting and independent, we must ask why the fact should be exhibited only in a few rare cases? The supposition resembles in partiality and capriciousness the Platonic immortality, conferred only on philosophers. Still, any complete view of the relations of mind and body should take account of these striking exceptions; and we

shall revert to them at a later stage.

The influence of mental changes upon the body is supported by an equal force of testimony. Sudden outbursts of emotion derange the bodily functions. Fear paralyzes the digestion. Great mental depression enfeebles all the organs. Protracted and severe mental labor brings on disease of the bodily organs. On the other hand, happy outward circumstances are favorable to health and longevity.

In the personifications so common in our early poetry, the various passions are described by the marks that their long dominance leaves on the bodily figure. In Sackville's "Induction," Dread is described as follows:

> Next saw we Dread all trembling, how he shook,
> With foot uncertain proffer'd here and there:
> Benumb'd of speech, and, with a ghastly look,
> Search'd every place, all pale and dead for fear.

And Misery:

> His face was lean, and some deal pined away,
> And eke his hands consumed to the bone.

In considering minutely the evidences of the connection of mind and body, we gradually perceive that the organ most intimately associated with mind is the BRAIN. Other organs have been assigned, at various times, as the special seats of mental activity, but these are now abandoned. Yet, although the brain is by pre-eminence the mental organ, other organs co-operate; more especially, the senses, the muscles, and the great viscera.

The peculiar structure of the brain will be afterward adverted to. For the present I remark that it is a very large and complicated organ; it receives a copious supply of blood, computed as one fifth of the entire circulation, a circumstance betokening great activity of some kind or other. Now the facts that connect the mind with the brain are numerous and irresistible. Let us rehearse a few of them, under the two aspects already stated: brain changes affecting the mind, mental changes affecting the brain.

Under the first topic, the commonest observation is the effect of a blow on the head, which suspends for the time consciousness and thought; at a certain pitch of severity it produces a permanent injury of the faculties, impairing the memory, or occasioning some form of mental derangement. It may also *remedy* derangement; there are cases on record where a blow on the head has cured idiocy.

All those abuses and casualties that impair the mental faculties act upon the nervous substance. Thus, stimulating drugs operate upon the nerves. Many instances of imbecility of mind are distinctly traced to causes affecting the nutrition of the brain.

The more careful and studied observations of physiologists have shown beyond question that the brain as a whole is indispensable to thought, to feeling, and to volition; while they have further discriminated the functions of its different parts.

Next, as regards mental changes leading to brain changes, or being associated with them, we can quote very extensive observations. Thus, after great mental exertion or excitement, there is an increase of the products of nervous waste. The alkaline phosphates removed from the blood by the kidneys are derived from the brain and nerves; and these are increased after severe exercise of the mind.

Again, violent emotions are among the causes of paralysis, which is a disease of the nerves or nerve-centres.

Most decisive of all, under this head, is the wide experience of the insane. Among the chief causes of insanity must be reckoned excessive drafts on the mind—as, for example, long and severe mental exertion and sudden mental shocks, usually of disaster and misfortune, but occasionally even of joy.

The association of brain-derangement with mind-derangement is all but a perfectly established induction. In the great mass of insane patients the alteration of the brain is visible and pronounced. I may quote as evidence on this head a pamphlet by Drs. J. B. Tuke and Rutherford, "On the Morbid Appearances met with in the Brains of Thirty Insane Persons." "The brains examined were those of patients whose deaths occurred consecutively, and were in no way picked on account of any peculiarity." The forms of disease exemplified were general paralysis, dementia with paralysis, chronic dementia, epileptic insanity. *In every case there was noticed a marked departure in one form or another from the healthy structure of the brain.* The authors enumerate nine species of morbid changes, discovered by microscopical examination. The occurrence of a case that presented no visible derangement would not be a conclusive exception, inasmuch as there may be alterations of substance that are not visible. It is believed, however, that in all cases of pronounced mental aberration, disease of the brain is present in a marked form.

A very instructive class of facts may be adduced, connecting mental action with the quantity and quality of the *blood* supplied to the brain. No organ is active without blood. The demand made by the brain corresponds with the extent and energy of its functions. Deficiency in the circulation is accompanied with feeble manifestations of mind. In sleep there is a diminution of the supply of arterial blood to the brain. General depletion lowers all the functions generally, mind included. On the other hand, when the cerebral circulation is quickened, the feelings are roused, the thoughts are more rapid, the volitions more vehement; great mental excitement is always accompanied with an unusual flow of blood, often outwardly shown by the throbbing of the vessels. In delirium the circulation attains an extraordinary pitch.

The blood must possess a certain *quality*, involving the presence of certain ingredients and the absence of others. Wholesome nourishment supplies the first condition of nervous and mental activity; inanition or starvation, feebleness of digestion, militate against the exercise of the mental functions. Moreover, the blood may be abundant and rich in nutritive matters, yet the organ of the

mind may be unduly depressed by the excessive drafts of the other interests of the system, as, for example, the muscles ; under great muscular strain there is very little capability of mental effort. Again, there are certain substances, known as stimulants, that are considered to supply the blood with an element specially provocative of nervous change, as alcohol, tobacco, tea, opium, etc.

The substances that must be absent include the so-called poisons, and the impurities of the body itself, which several large viscera are occupied in removing. The chief of these impurities are carbonic acid and urea ; either of them left to accumulate in the blood leads to mental depression, unconsciousness, and finally death. Hence the mental tone depends no less upon the vigorous condition of the purifying organs—lungs, liver, intestines, kidneys, skin—than upon the presence of nutritive material obtained from the food.

CHAPTER III.

THE CONNECTION VIEWED AS CORRESPONDENCE, OR CONCOMITANT VARIATION.

THE dependence of one thing upon another is ordinarily shown by two classes of facts—the first, the presence of the cause followed by the presence of the effect ; the second, the absence of the cause followed by the absence of the effect : as when we prove that lighting a fire is the cause of smoke, or oxygen the cause of putrefaction and decay. Of the two methods, the second —the absence of the cause followed by the absence of the effect—is the most decisive ; the preservation of meat by excluding air is the best proof that air, or some ingredient of it, is the cause of putrefaction. More especially convincing is the abrupt removal of a supposed cause, leading at once to the suspension of an effect.

There are cases, however, where we cannot make the experiment of removing an agent. We cannot get away from the earth where we live. We cannot remove the moon from its sphere, so as to see what actions on the earth depend upon it ; we cannot by an abrupt suspension of lunar gravitation prove that the tides are very largely dependent on lunar influence.

For such cases, recourse is had to a third expedient, which happily solves the difficulty, and furnishes the proof required. If the agency in question, although irremovable, passes through gradations whose amount can be measured, we are able to observe whether the effect has corresponding changes of degree ; and if a strict concomitance is observable between the intensity of the cause and the intensity of the effect, we have a presumption that may rise to positive proof of the connection. It is thus shown that the tides depend on the moon and the sun conjointly ; that the gaseous and liquid states of matter are due to heat.

In such a question as the connection of mind and body, the potent method of removing the cause is not applicable. We cannot dissect the compound, man, into body apart and mind apart ; we cannot remove mind so as to see if the body will vanish. We may remove the body, and in so doing we find that mind has disappeared ; but the experiment is not conclusive ; for in removing the body we remove our indicator of the mind, namely, the bodily manifestations—as if in testing for magnetism we should set aside the needle and other tokens of its presence.

Neither can the method of absence be employed upon the chief organ of mind — the brain. The removal of the brain is undoubtedly the extinction of the manifestations of mind ; but it is also, except in very low organisms the extinction of the bodily life. Important results are gained by partial removal of the brain, and we can reason from these to what would happen by removing the whole. This is the nearest approach we can make to the best form of experimental proof. The method of concomitance or correspondence is, however, applicable to the full extent. We can compare the gradations of the brain and nervous system through the animal series, and observe whether there are like gradations in the powers of the mind.

A considerable time has elapsed since attention was called by phrenologists to the connection between size of brain and mental development in human beings. The large heads of men distinguished for high intellectual endowments, or for great energy of character in other ways, have been contrasted with the small heads of idiots. The rule is not strictly maintained in every instance ; occasionally a stupid man has a larger brain than a clever man. But these are only individual exceptions to a prevailing arrangement. When extensive statistics are taken, the conclusion is established that great mental superiority is accompanied with a more than average size of brain.

The following is a table of the brain weights of several distinguished men :

Cuvier	64·5 oz.
Dr. Abercrombie	63 "
Daniel Webster	53·5 "
Lord Campbell	53·5 "
De Morgan	52·75 "
Gauss	52·6 "

The average male brain (in Europeans) is 49½ oz., the female 44 oz. (Quain's Anatomy 7th edition, p 571.)

Among idiots have been found brains weighing 27 oz., 25⅝ oz., 22¼ oz., 19⅝ oz., 18½ oz., 15 oz., 13 oz., 8½ oz.

According to Dr. Thurnan (*Journal of Mental Science* for 1866), the brains of insane persons are 2½ per cent below the average of the sane.

The concomitance of size of nervous system with mental power, through the animal series, is sufficiently admitted for the purpose of our general argument. The agreement is not strict, because the nervous system serves other functions besides those that are purely mental. The mere propulsion of the muscles demands a large supply of nerve force, and animals whose muscles are

large and active have correspondingly large brains. Thus it is that the maximum size of the brain is reached, not in human beings, but in the elephant tribe, and after them the whales, whose ponderous bodies demand an enormous muscular expenditure. The elephant's brain weighs from 8 to 10 pounds. The whale's brain is said to weigh from 5 to 8 pounds. The brain of one 75 feet long was found to weigh 7 pounds; Dr. Struthers found the brain of a young whale, 14½ feet long, 3 lb. 12 oz., of a tusk whale or sea-unicorn 17 feet long, 3 lbs. 14¾ oz.

In addition to propulsion of the muscles, a considerable amount of nerve force must be expended in supporting or aiding the processes of organic life—digestion, respiration, circulation, and other operations. The strongest proof on this point is the very great falling off in these various functions when the nerve force is monopolized for intense mental or muscular exertion.

It is found that tall men, as a rule, have larger brains than small men.

Comparing the increasing size of the brain with the increase in mental power, we are struck with the smallness of the one increase as compared with the other. An ordinary male human brain is 48 oz.; the brains of extraordinary men seldom reach Cuvier's figure, 64 oz. Now the intellectual force of the ordinary man is surpassed by Cuvier in a far higher ratio than this. Taking the mere memory, which is the basis of intellect, an ordinary man could not retain one third or one fourth, perhaps not one tenth, of the facts stored up in the mind of a Cuvier. The comparison of animals with human beings would sustain a similar inference. There would be no exaggeration in saying that while size of brain increases in arithmetical proportion, intellectual range increases in geometrical proportion.

A still more important and suggestive correspondence is discernible in the manner of working of the nervous system. Notwithstanding the radical distinction of nature between bodily action and mental action, we are surprised to see how closely certain circumstances of the one are conjoined with similar circumstances of the other. To understand this argument, a brief consideration must be given to the plan or mechanism of the nervous system.

Undoubtedly the best way of approaching the nervous structure is to commence from outside appearances. Every one is aware of the existence of sense organs and of moving organs; and more than that, each of us could recount a great many minute particulars respecting both classes. Now a study of these familiar facts suggests some of the deepest arrangements of the nervous structure.

The sense organs, usually reckoned five in number, are all more or less open to view. The organ of the sense of touch is the entire covering or integument of the body, the skin. The others are confined to special localities. By a sense organ is meant a portion of the body exposed to certain agents, and, when stimulated, giving birth to feelings of the mind. Each sense is suited to a particular class of influences: touch to solid pressures; hearing to aerial pressures; taste to liquid or dissolved matters having certain properties of a chemical nature; smell to gaseous effluvia of a like nature; sight to the rays of the sun or other luminous bodies.

The moving organs are all parts of the body—head, face, eyes, mouth, throat, neck, back, arms, legs, etc., etc. Every one of these goes through a great variety of changes of posture, alternations, combinations, and with greater or less rapidity and continuance. The motions are nearly all visible to the eye. The moving agents are concealed from outward view, but can be easily got at by dissection. The red flesh of meat, called muscular tissue, is a stringy substance made up into separate masses called muscles, of the most various shapes and sizes, but all agreeing in one property, called contractility or forcible shrinking. A muscle has its two extremities attached to bones or other parts, and in contracting it draws the two attachments nearer one another, and thereby effects the movements that we see. A broad spreading muscle placed over the temple and attached to the skull at one end, and at the other end to the lower jaw, when under contraction, closes the jaw in biting; the closure being accomplished with a certain energy, according to the size of the muscle and other circumstances. The large muscles of the fore part of the thigh are so placed as to straighten the leg when bent at the knee. The numerous movements of the human hand need a corresponding number of muscles. There are between four and five hundred muscles in the human body.

We must next consider the mutual relationship of these two sets of organs, sense organs and moving organs. Something needs to act upon a sense organ in order that we may get a sensation; and something needs to act upon a moving organ, or a muscle, in order to a movement. Both the one and the other are of themselves inactive or quiescent. The stimulus of the sense organs is generally apparent; a solid body touching the skin, a morsel in the mouth, a perfume to the nostrils, and so on. The stimulants of the moving organs are not so apparent: their origin is internal.

We are familiar with a large class of instances where a sense stimulus seems also to be a motor stimulus. A light anywhere appearing suddenly makes us turn to look at it. A morsel on the tongue awakens all the movements of mastication. Let us examine the facts more closely. My hand is lying quiescent on the table; something touches it lightly, a fly, or a feather; there is a rush of activity to certain muscles, and the hand is moved away. Well, supposing the two things to be remote cause and effect: the light contact—cause, the motion—effect: what may we suppose as to the *intermediate* links? Unless the process be something quite unique, there must be a channel of

communication between the skin of the hand and the group of muscles in the shoulder, upper arm, and forearm, that unite to withdraw the hand. Assuming the concurrence of ten muscles, there must be a ramifying thread of communication from any point in the skin of the hand to all those ten muscles. If a similar effect were to occur in the foot, the part moved would be the leg, showing lines of communication between the skin of the foot or leg and the muscles of the hip, thigh, and leg, of which a certain group concur in the single effect of withdrawing the foot.

Suppose now, instead of a light contact, the hand is sharply pinched in the very same place. The previous case shows the evidence of lines of communication between the skin of the hand and a group of muscles of the shoulder and arm, and we are prepared for a similar manifestation, perhaps more violent. We are not disappointed as to the violence; the same group of muscles appear to be roused, and to act more strongly; the withdrawal of the hand is greatly quickened. We find, however, that this is not all. With the mere arm movements are coupled a great many more—in the other arm, the legs, the body, and the face, besides the more concealed movements shown in the voice, which emits a cry, shout, or other exclamation. We see that any part of the skin of the hand is in connection with perhaps two hundred muscles; the notable circumstance being that a weak touch does not arouse the wider circle of movements. At all events, here is a fact showing the exceedingly numerous and complicated communications between a given portion of the skin and the moving organs. The complication grows upon us as we pursue our reflections upon ordinary facts. We remark that a similar pinch upon any part of the skin—hands, arms, legs, back — will induce a similar wave of effects; so that every portion of the integument of the body has its lines of communication with a very large number of muscles. Nay, farther, if we try similar experiments upon the other senses, we shall find similar effects; with a slight application, a limited class of movements; with a severe application, a wide display identical in general character with those due to a pinch of the skin. A very bitter taste, a malodor, a screeching discord, an intense flame, will each awaken movements of limbs, body, face, and voice. Every one of the senses is in the same extensive communication with the organs of motion.

The effects of a sense stimulation are not ended in a mere jump or attitude performed by a particular group of muscles; very often there is a long succession of movements and attitudes. This raises the complication still farther. The impetus of the sensation is sufficient to stimulate first one movement, then another, and another; showing a new class of lines of communication—those between the moving organs themselves. The bending of an arm is followed by its straightening; the closing of the jaws is succeeded by a lateral grinding motion. Now continuous movements cannot be maintained without a definite communication between each movement and its successor; walking and flying are rendered possible by an arrangement for connecting each movement with the one that regularly follows it.

It is needless, at this stage, to probe deeper that system of complicated intercommunication between sense organs and moving organs, and between one set of moving organs and another, involving hundreds or thousands of connections. These are as yet mere matter of inference; seeing that an effect is regularly followed by another at a distance, we presume the existence of some means of conveying an agency or force between the two localities. Not till we examine the interior of the body do we know what is the medium employed. On such examination we discover a set of silvery threads, or cords of various sizes, ramifying from centres to all parts of the body, including both sense-surfaces and muscles. These are the *nerves*. The centres whence they ramify are constituted by one large continuous lump, principally of the same silvery material, occupying the skull or cranium as a rounded mass, and continuing into the backbone as a long flattened rod, about half an inch across. The mass in the skull is the brain; the rod in the backbone is the spinal cord. The vastly numerous intercommunications, above shadowed forth, are effected through the nerves and these central masses.

The centres are, in by far the largest part, made up of the same material as the nerve-threads; they contain, however, an additional material. To the eye this second material has a different tint, an ashy gray appearance, as is seen by cutting into any portion of the brain or spinal cord of a man or an animal. This visible difference enables us to trace the distribution, and discover the proportions of the two kinds of material. In the brain of man and of the higher animals we see a curious arrangement of the surface into ridges and furrows, called convolutions, running in various directions; and the convoluted surface consists of a thin uniform cake of the gray substance, while the interior mass is principally made up of the white nervous matter.

The peculiarities of these two sorts of material have been exhaustively studied, and the significance of both is more or less perfectly ascertained or surmised.

Under the microscope, the white matter, constituting the nerve-threads wholly and the centres in great part, is seen to consist of *fibres* or very minute threads, every visible nerve being a bundle of these. The gray matter is a mixture of these fibres with a distinct class of bodies, called *cells*, *vesicles*, or *corpuscles*—small solid bodies, round, pear-shaped, or irregular, with prolongations to connect them with the nerves. These two elements—fibres and cells—together with inclosing membranes, blood-vessels, and cellu-

lar tissue, make up the nervous system, both centres and ramifications.

The first significant feature of the two nervous elements is the SIZE. Both are exceedingly minute. The large mass of nerve-substance is an aggregation of a very great number of very small fibres and corpuscles. The fibres range in thickness from $\frac{1}{1500}$ to $\frac{1}{12000}$ of an inch, the medium or average being $\frac{1}{6000}$ of an inch. There are two varieties of fibre; the chief, named "white," or "tubular" fibres, appear to consist each (1) of an outer structureless membrane; (2) of an interior surrounding layer of fatty matter; (3) of a central core or cylinder, which is not fatty, but albuminous (nitrogenous, or proteine) in composition. To this central axis is attached the proper function of the fibres; and at the two extremities of the nerves the axis appears alone, divested of its two envelopes: it does not exceed $\frac{1}{100000}$ of an inch in thickness.

The *cells* or *corpuscles* are of various shapes—round, oval, pear-shaped, tailed, and star-like or radiated. They consist of pulpy matter, with an eccentric roundish body or nucleus, inclosing one or more smaller nuclei, surrounded by colored granules. They range from $\frac{1}{300}$ to $\frac{1}{3000}$ of an inch in diameter. Although from the smallness in the amount of the gray matter as compared with the white, and from the greater diameter of the corpuscles, the number of these, in a cross section, is less than the number of fibres, yet as they lie in three dimensions, while the nerves lie only in two, their numerical aggregate is much beyond the aggregate of branching nerve-fibres, although not so great as the total number of fibrous connections.

The diagram Fig. 1 represents the cell in its various leading forms.

FIG. 1.

Nucleated nerve-cells magnified 170 diameters; *a* and *b* from the cerebellum; *c* and *d* from the medulla oblongata; *n* the nucleus of a cell.

In Chap. V. a diagram is given (Fig. 3) showing the continuation of the fibres into the corpuscles or cells.

We may now judge of the immense *multiplication* of nervous elements in the brain and nerves. Estimates have been made of the number of fibres in individual nerves. The third cerebral nerve (the common motor of the eye) is supposed to have as many as fifteen thousand fibres. In the sensory nerves the fibres are smaller; and in the large nerve of sight, the optic nerve, the number must be very great, probably not less than one hundred thousand, and perhaps much more. The number of fibres making up the white substance of the brain must be counted by hundreds of millions.

In this enormous multiplication of independent nerve-elements we seem to have the suitable provision for the vast number of communications needed in the ordinary actions of human beings, as above exemplified.

There are some significant facts regarding the ARRANGEMENT of the nerve-elements. It is to be noted, first, that the nerve-fibres proceed from the nerve-centres to the extremities of the body without a break, and without uniting or fusing with one another; so that each unfailingly delivers its separate message. Without this, the greatness of their number would not give variety of communication. The chief use of the two coatings or envelopes appears to be to secure the isolation of the central axis.

Remark, next, that the plan of communicating from one part of the body to another—as from the skin of the hand to the muscles of the arm—is not by a direct route from the one spot to the other, but by a nervous centre. Every nerve-fibre rising from the surface of the body, or from the eye or the ear, goes first of all to the spinal cord or to some part of the brain; and any influence exerted on the movements by stimulating these fibres passes out from some nervous centre. As in the circulation of letters by post, there is no direct communication between one street and another, but every letter passes first to the central office, so the transmission of influence from one member of the body to another is exclusively through a centre, or (with a few exceptions) through some part of the nervous substance contained in the head and backbone. Every communication is centralized; and, in consequence, there is not only great economy of the conducting machinery, but also an avoidance of conflicting messages.

When we speak of the nerves all ending in the nervous centres, we mean the *gray* substance, or the aggregate of fibres and corpuscles. Every nerve ends in a corpuscle; and from the same corpuscle arises some other fibre or fibres either proceeding back to the body direct, or proceeding to other corpuscles, whence new fibres arise, with the same alternative. Of the fibres of the brain and spinal cord the greater number connect corpuscle with corpuscle; a small number go outward to the muscles, forming the pathway of communication with the moving members.

The corpuscles are thus the medium of

connection of in-going with out-going nerves, and hence of communication between the outlying parts of the body. In them is organized that system of complicated correspondence whereby an influence in one part can arouse a wave of effects in many other parts. They are the crossings or grand junctions, where each part can multiply its connections with the remaining parts. There is not a muscle of the body that could not be reached directly or indirectly by a pressure on the tip of the forefinger; and this ramification connection is effected through the nerve-cells or corpuscles; just as, by means of the distribution of post-offices and lines of road, a letter from any village in Europe can be speedily sent to any other village.

A third point to be noted regarding the nerve elements—fibre and corpuscle—is their MATERIAL, composition, or quality. The active part (the core or central axis) of the fibres is composed of particles of an albuminous substance. The corpuscles are also made up of the same material, combined with fatty substances in granules. The substance of both is highly unstable, or easily acted on by external influences of every kind; but of the two elements the corpuscles are considered the most susceptible to change. We can but dimly conceive the precise mode of change that goes on in the one or in the other; it is a change that, when once begun, propagates itself along the whole line of open communications; and it is a change that finds a certain limit only by altering the structure of the nerve. The restoration from the altered structure is due to the blood, which circulates largely among nerve-fibres, but still more largely in the gray matter which contains the corpuscles; it has been computed (Herbert Spencer) that five times as much blood circulates in the gray or corpuscular substance as in the white or fibrous substance. In these imperfectly understood changes of the nerve-tissue we have the embodiment of what is called the nerve-force. This is an agent with various powers—mechanical agency, heat agency, chemical agency; all which are due to the molecular alteration of the nerve-substance, the complement of the change being a supply of blood in proportion to the force set free.

To return now to the tracing or correspondence and concomitance between mental acts and bodily changes. One grand correspondence is already implied, which will be afterward more fully discussed—the variety and multitude of our mental acts on the one hand, and the multitude of nervous elements on the other. If our nervous system consisted at most of one thousand ultimate fibres, and one thousand corpuscles, nobody could show how these could be manipulated so as to execute all the variety of the outward manifestations of feelings and thoughts. But great as is the number and variety of mental states, the nervous system, in its prodigious extent and multiplication, seems to show a correspondence by no means inadequate.

The correspondence of number of elements with complicacy of function is seen to advantage in the senses. The nerve of sight is the largest of the nerves of special sense; its ramifications in the retina are numerous and closely set. Nerve-corpuscles occur in that part along with the fibres, to increase the susceptibility to disturbance under a slight shock.

While in the more intellectual senses—sight, hearing, and touch—the nerves have their protecting and isolating sheaths corresponding with the distinctness and separateness of the parts of the impression; in smell, the nerves are a plexus of unsheathed fibres, corresponding with the fusion of the odorous impression into one whole, without distinction of parts (Spencer).

It has been pointed out by Mr. Spencer that to increase the delicacy of sight and hearing, where the impulse on the surface is very feeble, there are "multipliers of disturbance," or means of exaggerating the intensity of the shock. Thus, in the eye, the retina is composed of ultimate fibrils unprotected by their medullary sheath, and of nerve-corpuscles, which are more unstable than the substance of the fibres. In the ear, the little sand granules (otolites) and the rods, by being set in motion increase the action on the nerve of hearing.

The dark pigment of the eye, seen through the pupil as a deep brown shade, is an essential of good vision, being a means of intensifying the action of the light. Attention has been drawn by Dr. Wm. Ogle to the fact that pigment occurs also in the olfactory regions, and he traces to this fact an increase in the acuteness of smell. Dr. Ogle attributes the acuteness of the smell of the negroes to their greater abundance of pigment. Albinos and white animals neither see nor smell so delicately as creatures that are dark-colored. In the membranous labyrinth of the ear also, black pigment is found. ("Anosmia," by Dr. William Ogle, "Medico-Chirurgical Transactions," vol. liii.)

Facts such as these show how deeply the mental character may be affected by the structure of the material organs. A small difference in the pigment of a sense, by giving that sense greater susceptibility, may determine the animal's preferences, tastes, and pursuits; in other words, its whole destiny. In a human being, the circumstance of being acutely sensitive in one or two leading senses may rule the entire character—intellectual and moral. The contrast between a sensuous and a reflective nature might take its rise in the outworks of the sense-organs, apart even from the endowments of the brain. In this case the nervous system would follow the cue, instead of taking the lead, of the special senses.

Next, as to correspondences between mind and body, in respect to their mode of action. Notwithstanding the extreme difference of

the two kinds of activity, bodily and mental, we may yet find points of coincidence.

One remarkable coincidence is as respects *time*.

By a series of very ingenious and conclusive experiments, the rate of passage of the nerve-force has been shown to be about ninety feet per second. This measure is made upon the course of the nerve-threads, and does not include the passage through the gray matter of the centres with their mass of corpuscles. Now the time of a complete circuit of action, beginning at a stimulation of the senses, and ending in certain movements, depends partly on the time of moving along the nerves, and partly on the time of passing through the centres, where a number of corpuscles must be traversed. Estimates have been made as to this last operation, which, from the nature of the case, is likely to be somewhat various ; for not only may the central mass to be penetrated be of various extent, but also there is a liability to conflicting currents. The case of least internal delay is what is termed *reflex action*, where a motion answers to a stimulus, without the intervention of the will, as in the involuntary start from a pinch in the hand. By experiments on frogs, Helmholtz found that a period of from $\frac{1}{30}$ to $\frac{1}{10}$ of a second was occupied by the reflex act ; now the length of the entire nerve-tract could only be a few inches, which would hardly occupy the two hundredth of a second, if that tract were an uninterrupted nerve-thread.

The time occupied by a sensation and subsequent volition has been measured in circumstances where there were no conflicting impulses. This is done by ascertaining the time elapsing between the sensation of a signal and the answering by the hand. A comparison is made between two situations ; one where the person is prepared beforehand, by knowing where he is to be affected and what part is to move, in which case the attention is turned upon the proper points. The other situation is where a person does not know which part is to be struck, and which part is to be moved ; in this last case he has to exercise an active judgment or consideration, and the difference of time is about the $\frac{1}{14}$th of a second. Two persons are separated by a screen ; one is to utter a syllable and the other to repeat it as soon as possible. If the syllable has been agreed upon, the interval of repetition occupies from one sixth to one fourth of a second ; if it is not agreed upon, the interval is one twelfth of a second more. The example is put by M. Du Bois Raymond of a whale, ninety feet long, struck in the tail by a harpoon ; one second would be occupied in transmitting the impression to the brain ; a fraction of a second, say one tenth, in traversing the brain ; a full second in returning the motor impulse ; so that the boat would have upward of two seconds for escaping the danger.

Thus we have physiological evidence, on the one hand, that a certain time is occupied by the nerve-force, and we have mental evidence, on the other, that an equivalent time is occupied by sensation, thought, and volition. Our thinking can never transcend the physical pace of the nerve-force. Seldom do we think so rapidly as the nerve-force can move ; the reason is that we have so often to balance opposing considerations ; in other words, opposing streams of nervous influence come together, and keep one another in suspense for a longer or shorter time. The experiments above quoted show the minimum time of a mental decision.

Another correspondence related to time is the period required to produce a feeling or emotion. An appreciable interval must be allowed for the operation of any stimulus, in order that an appreciable feeling may be awakened—in order that we may be distinctly made conscious of a state of feeling. To become possessed of a sweet taste, some time must be allowed after the first contact with the nerve. Now this is in harmony with our legitimate inferences as to the nature of the nerve-force ; the molecular changes in the nerve-centres, which accompany states of feeling, occupy an appreciable interval of time. Further, a sensation does not decay at once, when the object is withdrawn ; nor does the molecular activity set up in the centres subside at once, when the nervous prompting ceases.

It is a safe conclusion, from our knowledge of molecular forces, that the molecular changes taking place in the nerves and the nerve, centres make an alteration of substance that soon reaches a limit, incapacitating the nerves for further change, until, by rest and assimilation, there has been a renewal of the old condition. Now to this there is an exact counterpart in our conscious experience ; every sensation or emotion is most lively when first excited, becomes fainter after a time, and at last is so completely worn out that the continuation of the stimulus has no effect. The apparent exceptions and the variations of degree prove the rule. One of the conditions of greater persistence in any feeling is long previous remission ; during a protracted interval of inaction the nerves and centres have been reinforced to a more than ordinary degree by the constant presence of nourishment while no expenditure has been demanded.

In the employment of external agents, as warmth and food, all will admit that the sensation rises exactly as the stimulant rises, until a point is reached when the agency changes its character, too great heat destroying the tissues, and too much food impeding digestion. There is, although we cannot fix it with numerical precision, a *sensational equivalent* of heat, of food, of muscular exercise, of sound, of light ; there is a definite change of feeling, a uniform accession of pleasure or of pain corresponding to an elevation of temperature of 10°, 20°, or 30°. So for each set of circumstances, there is a sensational equivalent of alcohol, of odors, of music, of spectacle.

It is this definite relation between outward agents and the human feelings that renders

it possible to discuss human interests from the objective side, which is alone accessible. We cannot read the feelings of our fellows ; we merely presume that like agents will affect them all in nearly the same way. It is thus that we measure men's fortunes and felicity by the numerical amount of certain agents, as money, and by the absence or low degree of certain other agents, the causes of pain and the depressors of vitality. And although the estimate is somewhat rough, this is not owing to the indefiniteness of the sensational equivalent, but to the complications of the human system, and chiefly to the narrowness of the line that divides the wholesome from the unwholesome degrees of all stimulants.

The simplest term that we can employ for a mental state is a *shock ;* a word equally applicable to the bodily side and to the mental side. A sudden stimulation of the eye, the ear, the skin, the nose, is called a shock, from its mere outward or physical aspect ; it is also called a shock mentally, not because the mental consciousness resembles a material thing operating on a surface of sense, as a ringing bell, but because there is a rapid transition from quiescence to excitement ; in which circumstance there is an accurate parallelism between the otherwise distinct physical and mental facts.

The special modes of our sensations show many curious correspondences of the physical and the mental. I select the more prominent. In the first place, let us reflect upon the ordinary experience of disease, into which mental symptoms enter as a regular concomitant. There are certain tissues that, from deficiency of nerves, are but little sensitive, as the bones, nails, hairs, etc. ; there being a gradation in this respect according to the extent of connection with the brain. Now, when any derangement operates upon the brain, directly, or indirectly, the physician looks for definite corresponding mental symptoms. The state of the mind is dictated by the state of the brain. As an example, note the mental symptoms of typhus fever, summed up in the phrase "febrile oppression." "There is great inaptitude for the exertion of the power of thought, or of motion. The expression of the face is dull and heavy, absent, puzzled ; the patient has the appearance of a person made stupid by drink," etc. In short, the mind is completely at the mercy of the bodily condition ; there is no trace of a separate, independent, self-supporting, spiritual agent, rising above all the fluctuations of the corporeal frame. The medical practitioner assumes that to every mental exchange there corresponds a physical change ; he is, to this extent, a materialist.

There is an interesting correspondence between the physical and the mental, in regard to a marked distinction among the sensations, in all the senses, between the *acute* and the *voluminous* or massive. A sharp prick in the finger, or a hot cinder, yields acute sensations ; the contact of the clothing of the entire body, or a warm bath, yields voluminous or massive sensations. Now it is observable that an acute sensation is due to an intense stimulus on a small surface ; a massive sensation to a gentler stimulus over an extended surface. The contrast is noticeable in every one of the senses. A gas-flame gives an acute feeling ; the diffused sunlight gives a massive feeling. A high note upon the flageolet is acute ; a deep bass note on the violoncello or the organ is massive. The sea, the thunder, the shouting of a multitude are voluminous or massive from repetition over a wide area. Taste is acute, digestive feeling is massive. Thus thoroughly does the mere manner of external incidence determine one of the most notable distinctions among our states of feeling.

CHAPTER IV.

GENERAL LAWS OF ALLIANCE OF MIND AND BODY.

WE shall now give an account of the most general laws of connection of mind and body. This is a difficult subject, and far from being mature ; yet enough is known to gratify curiosity, and to impart useful lessons.

We have already seen grounds to believe that for every mental shock, every awakening of consciousness, every mental transition, there must be a concomitant nervous shock ; and as the one is more or less intense, so must be the other. Such is the most general circumstance that we are able to assign regarding the connection. Although a very important point to establish, yet this is too vague to satisfy us.

Mind is now generally admitted to have a threefold aspect—three different functions—expressed by FEELING (including emotion), WILL, or volition, and THOUGHT or intellect. These are a trinity in unity ; they are characteristic in their several manifestations, yet so dependent among themselves that no one could subsist alone ; neither will nor intellect could be present in the absence of feeling ; and feeling manifested in its completeness carries with it the germs of the two others. Hence, although, in tracing out the bodily accompaniments of mind, we shall view the three powers in separation, we may expect to find certain great laws pervading the whole.

THE FEELINGS.

We all know pleasure and pain, and we are familiar with states of excitement that are neutral or indifferent. When feeling is opposed to will and to thought, it is most characteristically represented by pleasures and pains ; these are never confounded with thought, and although they are motives to the will, they do not make up the will. But there are many occasions when we are excited, roused, or rendered conscious, without being exactly pleased or pained : and when we are not properly either willing or thinking. Such is a mere shock of surprise ; such also are the excitements that often accom-

pany the waning of our proper pleasurable and painful states. After the pain of a fright has passed away, there remains a state of feeling as neutral excitement. Now there are laws common to feelings generally, and laws referring to pleasures and pains particularly.

Next to the vague statement that every mental shock is accompanied by a corresponding nervous shock, is the law that assigns a physical counterpart to the most fundamental and general attribute of the mind, commonly termed the law or principle of relativity.

Law of Relativity.

(Applies both to Feeling and Thought.)

CHANGE of impression is necessary to our being conscious.

First, on the MENTAL side :

It is a familiar observation that an unvarying action on any of our senses has, when long continued, the same effect as no action at all. We are not conscious of the pressure of the atmosphere. An even temperature, such as that enjoyed by the fishes in the tropical seas, leaves the mind an entire blank as regards heat and cold. The feeling of warmth is not an absolute, independent, or self-sustaining condition of mind, but the result of a transition from cold ; the sensation of light supposes a transition from darkness or shade, or from a less degree of illumination to a greater. To use a familiar illustration, a watchmaker is not conscious of the unintermitted ticking of his clocks ; but were they all suddenly stopped, he would at once become aware of the blank.

We should be astonished if a law so pervading had not been frequently remarked and expressed in literature. It has been recognized many times in forms more or less definite. One of the most definite expressions of the law was given long ago by Hobbes : "It is almost" (he should have said *altogether*) "all one for a man to be always sensible of one and the same thing, and not to be sensible at all of anything."

The principle has been recognized more fully in its application to the emotions. People are generally aware that the first shock of transition from sickness to health, from poverty to abundance, from ignorance to insight, is the most intense ; and that, as the memory of the previous condition fades away, so does the liveliness of the enjoyment of the change. Shakespeare speaks of the miser's looking but rarely at his hoards for fear of "blunting the fine point of seldom pleasure ;" and makes the versatile Prince Hal say that

> If all the year were playing holidays,
> To sport would be as tedious as to work.

The blessings of leisure, retirement, and rest are pleasant only by contrast to previous toil and excitement. The incessant demand for novelty and change, for constant advances in wealth, in knowledge, in the arrangements of things about us—attest the existence and the power of the law of relativity in all the provisions for enjoyment. It is a law that greatly neutralizes one part of the advantages of superior fortune, the sense of the superiority itself, but leaves another part untouched, namely, the range, variety, and alternation of pleasures.

It is beyond my present limits to show how the principle of relativity appears in all the fine arts under the name of contrast, how it necessitates that in science and in every kind of knowledge there should be a real negative to every real notion or real proposition ; straight—curved ; motion—rest ; mind—extended matter or extended space ; how, in short, knowledge is never single but always double or two-sided, though the two sides are not always both stated. I must be content with this very brief illustration of the principle itself, and now advert to the physical counterpart.

Secondly, on the PHYSICAL side.

The chief point here is to conceive by what arrangement of the material organization a continued agency ceases to produce that amount and kind of nervous action requisite for consciousness.

One fact of the nervous action has already been noticed. The nerve-pores and corpuscles, on being stimulated, undergo a process of change, whereby their power is gradually exhausted ; in consequence of which they need remission and repose. Hence, the first moments of a stimulus are always the freshest, and give birth to the most vivid degrees of consciousness. This is the condition more especially requisite for maintaining a state of pleasurable sensibility. The nervous system should be duly refreshed or invigorated by nourishment and repose, and never pushed in any part to the extreme limits of exhaustion. The same condition applies to our power of active energy in every department, whether intellectual, voluntary, or emotional. Power is at the maximum, under a fresh start of renovated nerves, and fails as we approach the point of exhaustion. There are certain exceptional manifestations, as in the common experience of "growing warm" to one's work ; the maximum of energy usually shows itself some time after commencing : an effect due entirely to the increased supply of blood following on a certain amount of exercise.

This fact is of the highest practical importance, and corresponds to some of our experiences in connection with the law of relativity or change of impression ; but it does not amount to the full significance of that law. Two circumstances still remain to be accounted for.

In the first place, the dependence of intensity of consciousness on *the degree of the transition*—as when in passing from one temperature, or one shade of light to another—is the most precise and characteristic feature of the law of relativity. Now, the degree of transition is connected with the degree of disturbance of the nervous currents, whether it be the quickening of the nerves from a dormant condition, or the alteration of a settled pace

to which the system has accommodated itself.

Two views may be taken of the physical adjuncts of the state of unconsciousness, the state opposed to mental wakefulness. Either the nervous mass as a whole is quiescent, that is, unagitated by currents of nervous energy, which might be supposed to be the condition of profound slumber; or currents are still kept up, but at an even, settled, unaltering pace. There are facts and analogies in favor of both views. The mode of stating the ultimate physical condition of all consciousness depends upon how we decide between the two suppositions.

As regards the first, it would seem natural to suppose that the nerves pass from the state of perfect repose to a state of greater or less activity or excitement, according as they are roused by stimulation, and that we are made conscious accordingly; while the remission of the stimulus, and their own exhaustion, tend to quiescence and to unconsciousness. If we had no facts pointing to a different conclusion, we should adopt this as the most conformable to all analogy. But there are facts pointing the other way. The nervous system is rarely allowed to fall into entire somnolence. In profound sleep the reflex actions go on; these, however, we may disregard, as having detached themselves from the conscious circles. Still, although when awake we keep up activity more or less, and are under the stimulation of several senses, yet we often become almost unconscious of either the activity or the sensations; the only thing necessary for this result is that there shall be for the time monotonous or invariable. The most likely interpretation to be pu upon so familiar an experience would seem to be that there are *always* currents of nerve-force, but that consciousness disappears according as these are unvaried in their degree. Many of the best-established facts of the system are in favor of a certain low degree of nerve action as existing under every variety of state; such, for example, as the muscular tension maintained in the most perfect sleep.

On this hypothesis our conception is, that when all the currents of the brain are equally balanced, and continue at the same pitch—when no one is commencing, increasing or abating—consciousness or feeling is null, mind is quiescent. A *disturbance* of this state of things wakens up the consciousness for a time; *another* disturbance gives it another fillip, and so on; the variety of stimulus in the waking state forbidding the perfect equilibrium from being attained. In harmony with this supposition is the really fitful nature of the mind; the stream of consciousness is a series of ebullitions rather than a calm or steady flow. The calmness that we actually experience belongs to a low or moderate excitement: let there be any considerable intensity of feeling, and the ebullition character will start out convincingly prominent.

In the present state of our knowledge, no certain decision between the two conflicting hypotheses should be hazarded. We must wait for an *experimentum crucis*, and perhaps the real state of the case is not accurately expressed by either.

The foregoing discussion embraces the law of pure relativity, change, or transition, as connected with mental wakefulness or consciousness. But in the concrete examples of the mental fact as above expressed, there is a further circumstance not involved in what has now been brought out. We have made allowance for the decay of an impression after a certain continuance, leaving still the possibility that, after a suitable remission or interruption, the impression may be renewed in all its fulness.

But now, among the features of those experiences given from the mental side of relativity, this stands out prominent, namely, that no *second occurrence* of any great shock or stimulus, whether pleasure, pain, or mere excitement, is ever fully equal to the first, notwithstanding that full time has been given for the nerves to recover from their exhaustion. There is a certain amount of decay in the force of every impression, on the after-occasions when it is revived. Such is the statement of the law of novelty, with which we are all familiar.

In all probability we have here only a new and more complicated phase of the law of transition. We need to suppose that the system accommodates itself to every new state of things, that a permanent trace is made (through the operation of the retentive power), and that under a fresh shock this accommodation operates by diminishing the interval of transition, the difference between the present impression and the pre-established attitudes and arrangements of the nervous system.

It is needless to push this speculation beyond a general surmise. Until a more precise expression can be given to the modes of the nervous action under the single circumstance of mere transition, permanent accommodation being left out of account, we cannot hope to deal with the complication of two circumstances. Still, a reasonable probability attaches to the hypotheses of physical action that have now been suggested.

LAW OF DIFFUSION.

When an impression is accompanied with feeling, the aroused currents *diffuse* themselves freely over the brain, leading to a general agitation of the moving organs, as well as affecting the viscera.

Illustrative Contrast.—The so-called reflex actions (breathing, swallowing, etc.) are commonly said to have no feeling; at the same time, they are accomplished in a limited circuit or channel.

Note of Explanation.—It is not meant that every fibre and cell can be affected at one moment, but that a spreading wave is produced sufficient to agitate the body at large.

We have seen generally what it is that nervous action consists in. A stimulus on a

sensitive surface affects a sensitive nerve. It thence proceeds to some ganglionic centre, there liberating a still more energetic force, which passes by motor nerves to muscles. The completed fact of a nervous shock is a muscular movement. But, owing to the numerous cross connections that make up the aggregate of corpuscles, or the gray central matter, the sensory stimulus proceeds first to one corpuscle, and then is diffused to others successively, until it affects a great many before it reaches motor nerves; and when these are reached they are so numerous as to actuate a wide circle of movements. Now it is found that consciousness or feeling increases with the extent of the wave, or the number of the central corpuscles excited and the consequent number of outward movements commenced. Feeling is only nascent in the case of a simple sensory stimulus, one passing through a limited group of corpuscles, and producing a simple movement. We cannot say that even then consciousness or feeling is absolutely non-existent; but it begins to be decisively manifest when the wave spreads right and left, by the corpuscular crossings; and it grows with the extension of this wave. We assume, as a fundamental fact, that, with nervous action, feeling begins. We cannot draw a line between nervous action without feeling, and nervous action with feeling; we can only indicate a scale of degree. Yet, to all intents and purposes, there is a division of nervous actions into unconscious and conscious, which is illustrative of the general law of diffusion.

The reflex actions—breathing, the movements of the intestines, the heart's action, winking, etc.—are known to be stimulated through the spinal cord, and its immediate continuations at the base of the brain; they do not involve the cerebral mass. The responding movements in the case of each of them are limited to the work to be done: to the chest, in breathing; to the intestines, in propelling the food; to the muscles of the heart, in pumping the blood. These actions are unaccompanied with feeling. So, in touching the hand of one asleep, we see the hand curl up, or the arm move away. This is called reflex; it is prompted through the lower centres, without lateral diffusion or communication, and it is directed to a single local group of muscles. In such examples, as formerly seen, the limitation is owing to want of force. There are ways open to the brain; but they are not entered at the instance of a very feeble contact. Still, the fact of limitation of range is accompanied by the fact of unconsciousness: an isolated response is our evidence for contraction of the sphere of excitement; and such isolated responses are little, if at all, accompanied with feeling.

Compare now what happens in a shock, say of acute pain, as from a severe smart or a wound in the same part, namely, the hand, A reflex influence would still operate, and give birth to movements of the arm; but these would be a small part of the case. The bodily members everywhere are put in motion; the features are contracted with a well known expression; the voice sends out a sharp cry; the whole body is thrown into agitation. Nor do the effects stop with mere muscular movements; the face is flushed, showing that the circulation is disturbed; the breathing is quickened, or the reverse; a temporary loss of appetite proves that the gastric secretions in the stomach are perverted; the skin is deranged; and in the feminine constitution it would appear as if the mother's milk were turned into gall. In order to cause this wide circle of effects, the influence of the shock, the nerve-currents set on, must be not merely intense in degree, but highly diffused in their course through the brain; being thus able to reach and to actuate the general system of out-carrying nerves.

I have taken an extreme case to present the law in its utmost prominence. We might vary the illustration, and show that according to the strength of a feeling is *the extent of the diffusion*, as well as the intensity of the diffused manifestations. The rise and fall of these two facts, in steady concomitance, is among our most common experiences; indeed, our principal means of interpreting the strength of one another's feelings is derived from this uniformity. It would also be easy to prove that the apparent exceptions to the law are not real exceptions; that in very mild states of feeling, or under a faint degree of excitement, the diffused wave is not strong enough to excite the muscles to an open display; that the will may suppress the display; that habit may suppress it; that, when the system is so strongly pre-engaged by another influence as to resist a new diffusion, impressions are not felt (as in the insensibility to wounds in a battle).

I will not dwell on these illustrations, and will merely add a reference to the operation of habit in deadening the feeling that accompanies our actions, to show that, wherever this deadening influence has occurred the diffused wave is proportionately contracted and suppressed In our first attempts to write, to cipher, to play on an instrument, to speak, or in any other work of mechanical skill—the inward sense of labor and difficulty is corresponded to by the number of awkward and irrelevant gesticulations. On the other hand, in the last stage of consummated facility and routine, the consciousness is almost nothing; and the general quietude of the body demonstrates that the course of power has now become narrowed to the one channel necessary for the exact movements required. This is a sort of educated imitation of the primitive reflex movement adduced at the outset; the comparison is so striking as to suggest to physiologists the designation of secondary reflex or automatic, for the habitual movements. A man at a signal post, after long habit, is subjected to little or no nervous influence, except in the single thread of connection between a certain figure depicted on the eye and a certain movement of the hand; the collaterals of the

primitive wave have died away, and the accompanying consciousness has fallen to a barely discernible trace.

The law of diffusion might be called in to confirm the hypothetical account of the process of accommodation adverted to under relativity. The failing intensity of renewed impressions might be connected with a narrower and weaker diffusion. Now, our study of the physical basis of retentiveness (see chap. v.) shows the tendency of all nervous states, by repetition, to narrow their compass of action, and to run into special channels of connection with the states that happen to succeed them; substituting intellectual trains for emotional outbursts.

It is by combining the two laws—relativity and diffusion—that we obtain the comprehensive statement of the physical conditions of all consciousness: *An increase or variation of the nerve-currents of the brain sufficiently energetic and diffused to affect the combined system of the out-carrying nerves (both motor nerves and nerves of the viscera).*

To all the varieties of human feeling, there correspond (we must suppose) varieties of diffusion in the brain, as there correspond, to a very considerable extent, varieties in the external manifestation. The outward signs are only a small part of the wave of effects upon muscles and viscera; many movements receive a mere incipient stimulus, too weak for producing action (not to speak of counter-impulses of suppression), and most of the visceral alterations fail to show themselves to the observer. The diffused wave of nervous energy is an inseparable adjunct of feeling. The consequent manifestations of movement and gesture are the universal language of feeling, and possess a constancy that, among all the variations of human character, is truly remarkable. This is what I previously put forward as the first argument for the thorough connection of mind and body; the region of facts most open to vulgar observation, and yet most persistently overlooked by the supporters of the dissociation or independence of mind and matter.

The varieties of expression of the feelings constitute a study of great interest as regards our present theme; but it will be enough to advert, under the following head, to the one broad and characteristic distinction of pleasure and pain.

LAWS OF PLEASURE AND PAIN.

Pleasure and pain have certain well-known agents or causes, and they have also a characteristically distinct outcome of demeanor and expression. It is an interesting, although not very easy, problem to sum these up in a general law, or laws, of concomitance of mind and body. The principle that regulates feeling in general is liable to considerable modification, according as the feeling assumes the character of either pleasure or pain.

As a preliminary remark, it must be allowed that pleasure and pain are diametrically opposed, like cold and heat, up and down, debt and credit, plus and minus. The two are mutually destructive, they neutralize each other, like cold and heat. Hence the circumstances present in connection with the one must be absent, if not reversed, in the case of the other; whatever mode of nervous excitement is allied with pain, its opposite must be allied with pleasure. Thus one explanation should include both.

LAW OF SELF-CONSERVATION.

The remark has occurred to various speculators that there is a close connection between pleasure and high vitality, or the vigor of the system, and between pain and the causes of diminished vitality or the feebleness and exhaustion of the system. Plato and Aristotle, in their views regarding pleasure, included its being a restorative to nature. Kant has a few striking expressions of the same tendency, although their effect is greatly spoiled by the context: "Pleasure is the feeling of the furtherance, pain of the hindrance of life." A very large number of the facts may be included in the following statement, which may be termed the Law of Self-Conservation:

States of pleasure are connected with an increase, states of pain with an abatement, of some or all of the vital functions.

This principle resumes such well-known experiences as these: the pleasures of healthy exercise, and of rest after toil, the pain of fatigue; the pleasures of nourishment and pure air, the pains of hunger, inanition, or suffocation; the pleasures of health generally, the pains of bodily injury and disease. These few instances sum up the ruling facts of every one's daily life and bodily and mental condition.

There are, however, a few startling exceptions. For example: cold may be painful and yet wholesome, as in the cold bath, and under the keen bracing air. But this exception, on closer view, confirms the general rule, while rendering its application more definite. Cold undoubtedly depresses, for a time, one very sensitive organ, the skin, perhaps also the digestive organs; while, in moderate degree (that is, the degree constituting wholesomeness) it exalts, through the capillary circulation, the lungs, the heart, the muscles, and the nerves; and the contrast teaches us that, as far as *immediate pleasure* is concerned, we lose more by depressing the functions of the skin and the stomach than we gain by increasing the power of the heart, the lungs, the muscles, or even the nerves themselves.

Another very remarkable exception is the painlessness of many diseases, together with the occasional absence of all pain, and even the presence of great comfort, in the sick-bed and in the final decay of life. This is the case so often pointed to as evincing the triumph of the mind over the body.

The remark already made in the case of cold must be still further extended to meet this case. The connection of pleasure with vitality, and of pain with feebleness or loss of function, does not apply to all organs

alike; some are comparatively insensitive, their degeneracy and decay seem unaccompanied with feeling; while in others the smallest functional derangement is productive of pain. Muscular weakness does not give pain, unless we are compelled to efforts beyond our strength; also the nervous system may be enfeebled as regards thinking power without producing discomfort, provided we are allowed perfect repose. On the other hand, anything that impairs nutrition, as indigestion, leads to immediate discomfort; and still more decided is any partial stoppage of the purifying organs, as the intestines, the liver, the skin, the lungs, or the kidneys. There are forms of degeneration of the heart, the lungs, the kidneys, and other parts, that do not interfere with the usual functions; their evil consists in preparing the way for a sudden break-down.

The powers of the nervous system are various and even mutually opposed. Intellectual feebleness, decay of memory, and incapability of thought are not painful in themselves. There is, probably, a distinct power of the nervous system, connected with the pleasurable tone of the mind, which may not fail, when the intellect fails, or may fail, while the intellect is yet vigorous; a function very unequally manifested in different individuals.

The mental effect of diminished power in the various organic functions is ultimately realized by some failure in the brain itself. Could we suppose the brain to maintain all its functions, derangement might exist in other organs without depressing the mind. Strictly speaking, this is an impossible concurrence. But there is sometimes an approach to this situation, namely, when the blood, such as it is, flows in excess to the brain, supporting its powers at the expense of all other interests; an arrangement that cannot be permanent, although it may last for a little time. In such a contingency there is an extraordinary exaltation of mental function, including a hilarious and even ecstatic enjoyment. It is the state that narcotics may produce, for a brief moment, in a constitution partially wrecked; and it occasionally occurs in the closing hours of life. We often see patients in the last stage of consumption, still entertaining the most sanguine prospects of recovery; a proof that, instead of being mentally depressed, they are in the opposite or joyous condition. On this it is remarked by Dr. Patrick Nicol ("Medical Reports of West Riding Asylum for 1872," p. 199) "that blood, from which tubercle is deposited, appears to have that peculiar injurious property for the brain *which excites delirium;*" in extreme cases, it is productive of raving madness.

The general principle, connecting pleasure with increase of vital power, receives further confirmation from the outward displays under pleasure and pain; the animation, stir, and vigor under the one, and the drooping and collapse under the other.

The primary law of feeling, that movement is in proportion to intensity of stimulation, is greatly modified according as the feeling is pleasurable or painful. Mere intensity of stimulus operates to give intensity of movement; but the character of the feeling as pleasure, as pain or as neutral excitement, must also be taken into account.

The designations for pleasure are very significant of the difference: the epithets—lively, animated, gay, cheerful, hilarious—are expressive of unusual activity; the epithets—sad, miserable, woe-begone, depressed, sorrowful, dejected, crestfallen—suggest languor, prostration, inactivity. With the young, we see in especial prominence the union of the two facts—mental delight and bodily energy. The examination of the organic functions conclusively shows that in a pleasurable mood these are raised in efficiency; the respiration is quicker, the pulse is better, the digestive functions are exalted. In depression and pain, all is reversed. An apparent exception to the law occurs in the stimulating effects of an acute smart, and in the contortions and struggling of pain generally. This, however, is no real exception, as the following considerations will show.

In the first place, many painful shocks are simply and solely depressing; they have not even the pretence or appearance of rousing the energies. A blow on the shin is utterly prostrating; the irritation of a raw wound has much the same effect. Certain parts of the body, on being squeezed, compressed, or tortured, yield an intense pain that at once quenches all the energies. Cold, in its painful forms, excepting, perhaps, the contact with a small congealed surface, which resembles a scald, is mainly depressing; when it reacts to exalt the functions, its painful character disappears. Privation, calamity, severance of ties, shame, remorse, are accompanied with general prostration of the energies.

In the next place, the vehement muscular stimulation due to acute pains can be shown to be accompanied with loss of power in the organic functions; it is thus a mere spasmodic display, the result of a spendthrift energy. The stomach, the heart, the lungs, are all depressed, to support a wasteful exertion of muscle.

That the exertion is forced and factitious is further proved by the lassitude that succeeds; the muscles themselves show an exhaustion very different from what would follow on a similar amount of healthy exertion, or in the excitement of joy.*

Still, an acute smart is one mode of temporarily raising the energies; the acuteness im-

* There have occurred many instances of death, or mental derangement, from a shock of grief, pain, or calamity; this is in accordance with the general law. Instances are also recorded of death and insanity from excessive joy; but they are so rare as to have the character of exceptions. Extreme intensity of shock, whatever be its character, is unhinging; but there is a wide difference in the consequences, according as it is the intensity of pain or the intensity of pleasure. From the one shock, people, as a rule, recover slowly and with difficulty; from the other they recover rapidly and easily.

plying that the pain is limited to a very small circle of nerves, so that the injurious effects are confined, while the stimulus suffices to arouse a wave of force-bearing nerve-currents. The light smart of a horsewhip is enough to waken the energies, without damaging the vitality. The pain of a flogging, which multiplies smarts of still greater intensity, is utterly exhausting to the whole system.

In this law of pleasure and pain we have the key to the leading varieties of expression of the feelings. The organs of expression by movement are primarily the features, next the voice, lastly the movements and gestures of the body at large—head, trunk, and extremities. In pleasurable emotions, these are unquestionably rendered active; the grimaces, gestures, and attitudes show an accession of active power. The notable circumstances in this display are the general erection of the body, the opening up of the features, the powerful exercise of the voice; all showing that the extensor muscles, which are by far the largest, are strongly stimulated. When we have surplus energy to expend, we stretch and extend the body in preference to bending and relaxing it; the weight of the body itself is borne in the one case and not in the other. Any additional strain, as in walking, lifting weights, rowing a boat, is borne by the extensor muscles. It is the size of these that makes the muscular figure, the fulness of the calves, the thighs, and the hips.

On the other hand, pain (not violently acute), dejection, depression, leads to the relaxation of all these powerful muscles; hence a general stooping and collapse of the figure, showing that the springs of muscular force have dried up. The difference of the two situations, as regards the carriage of the whole body, is most marked. Compare the victor in a triumph with one of his captives —the attitude of the beater with the beaten. And as regards the face, how much is suggested by the one descriptive trait, "His countenance fell"!

To this general law we find a remarkable exception that puzzled the great physiologist, Müller of Berlin, and was left unsolved by Sir Charles Bell. It refers to the expression of the face. While the movements under pleasure are obvious and energetic—the raising of the eyebrows, the drawing outward of the angles of the mouth, there are also some apparently energetic movements characteristic of pain—the lowering of the eyebrows, the wrinkling the forehead, the drawing down of the angle of the mouth, the pouting of the lower lip. Now, to have one set of muscles acting strongly under pleasure, and another set acting strongly under pain, would merely be two modes of activity; it would not represent opposition or contrariety. Yet pleasure and pain are as opposite as heat and cold. What causes the one arrests or destroys the other; and no theory of the physical accompaniments is complete that fails to bring out this contrariety. It would be a self-contradictory account of solvency and insolvency, to say that one was property in the funds, and the other property in land; and there is an equal contradiction in having muscles of pleasure and muscles of pain.

One way of diminishing the difficulty is to carry out a little further the foregoing contrast of the attitudes in pleasure and in pain —the one erect, the other collapsed. In addition to remitting the powerful exertion of extending the body, one might suppose the flexor muscles extended to make it still more thoroughly collapse, to distend to the utmost the strong erecting muscles. Now, one effect of this would be to release the muscular currents, and to set free the blood and the nerve-force in favor of the other interests of the system—digestion, etc., which are the first to suffer in great pain or in dejection of mind. The cost of the flexor effort is but small, and the return in the liberation of the nervous and muscular currents might more than compensate for that cost. The contrariety of the two states would be saved, while there would still be an active prompting under pain.

Applying this explanation to the face, we should have to consider whether the muscular opposition in it could show, in the one case, the exertion of powerful muscles, and in the other, their relaxation by the operation of those of smaller calibre. A slight exertion of the small muscle that corrugates the eyebrows may be supposed to perfect the relaxation of the more powerful muscle of the scalp that raises the eyebrows; a small stream of energy in the muscle surrounding the mouth relaxes more thoroughly the strong zygomatic muscles, and the buccinator, which are distended in smiling and laughter. By the employment of a slight force, we may be supposed to release a greater quantity; so that, after all, the positive exertion of those specific muscles of pain would merely aid in renouncing muscular energy on the whole. We should thus assign as the reason why a forced "sadness of the countenance makes the heart better," that, by the employment of a certain amount of stimulus, we more thoroughly abate the stimulation of the moving organs at large, and allow blood and nervous force to pass to the enfeebled viscera —the digestion, the lungs, the heart, the skin —by whose amelioration the mental tone is decisively improved.*

* A new turn has been given to the explanation of the facial attitudes under pleasure and pain, first by Mr. Spencer, in the new edition of his Psychology, and next in Mr. Darwin's recent work on Expression. The novelty lies in applying the Doctrine of Evolution, or inheritance, to account for the more special and characteristic modes of expression of the face, as, for example, frowning, smiling, pouting, and depressing the corners of the mouth. The same doctrine is also applied to account for the expression of the more marked passions, as fear, love, anger.

It does not lie within the plan of this work to discuss the details of the human feelings, either in their internal characters or in their outward display; nor is it my purpose to enter into the merits of the doctrine of Evolution as applied to the mind. So far as I have here gone, in assigning the most general laws of connection of mind and body, I am not at variance with any views set forth by these two great authorities, although I have given far more prominence than

An examination, after Sir Charles Bell, of the two great convulsive outbursts—laughter and sobbing—gives an unequivocal support to the law; the one signifies in all its points the accession of vital force; the other equally signifies loss, failure, or deprivation of energy. "The whole expression of a man in good spirits is exactly the opposite of one suffering from sorrow" (Darwin, p. 213). In both cases there may be energetic displays; but while the energy of laughter leaves no sting behind, the energy of convulsive grief is succeeded by utter prostration.

The law now illustrated is named the law of self-conservation, because without it the system could not be maintained. Inasmuch as we follow pleasure and avoid pain, if pleasure were injurious and pain wholesome, we should soon incur entire shipwreck of our vitality, as we often partially do, through certain tendencies that are exceptional to the general law.

LAW OF STIMULATION OR EXERCISE.

To stimulate or excite the nerves, with a due regard to their condition, is pleasurable; to pass this limit painful.

The mere presence of nourishment, that is, blood, does not evoke all the nervous activity that the blood can pay for, and the nerves maintain with safety; the case is ratner that the blood yields up force at the instance of stimulated nerve-currents. Now this stimulation, when in the proper degree, is connected with pleasure, while there is a degree that is always painful; both points varying with the condition of the individual.

If we commence the illustration from the side of pain, we may notice as two leading circumstances, (1) conflict, and (2) intensity.

First. To say that all *conflicting* stimulations are painful is merely to state a consequence of the former position. Conflict is waste of vital power, and is likely to be accompanied by a depression of the mental tone. This simple and obvious maxim sums up a wide experience; it includes the pleasures of harmony and the pains of discord; the pleasures of a free scope to all our impulses and the pains of constraint, obstruction, and thwarted aims; the pleasure of discovering similarity, agreement, consistency, and unity, the pains of inconsistency and contradiction.

Secondly. As regards *intensity*. Violent, excessive, and sudden stimulations induce pain on various grounds. In opposition to the law that connects pleasure with vital energy, they cause a momentary exhaustion of the power of the nerves affected; and they may further be considered as originating a conflict with the prevailing currents of the brain, which do not adjust themselves at once to the new impetus. Thus though, on the general principle of relativity, they waken up a strong feeling, they sin against the conditions of *pleasurable* feeling.

Conflict and violence, then, are two principal modes of painful stimulation, and explain a very considerable number of our pains. In most, if not in all, of the painful sensations of three of the senses—namely, touch, hearing, and sight—the pain is either discord or excess. The smarting acuteness of a blow on the skin, of a railway whistle close to the ear, of a glare of light—are due to the mere degree or excess of the stimulus. In hearing and in sight, there are, in addition, the pains of discord. In the two remaining senses, taste and smell, we cannot make the same affirmation. We do not know what is the mode of nervous action in a bitter taste, as quinine or soot; and we cannot say that the transition from sweet to bitter is a transition from moderate stimulus to an excessive one. It may be that the power of the nerve is exhausted under a different kind of influence from mere violence of stimulation; but no certain knowledge exists on the subject. The same remarks apply to smell.

These observations on the *negative* aspect of stimulation—the aspect of pain—contain by implication the positive aspect. Stimulation, as such, is pleasurable. "Man loves sensation," said Aristotle. For the eye to see, for the ear to hear, for the skin to touch, are in themselves agreeable. We cannot affirm, with respect to the ordinary gratification of the five senses, that they increase vitality—they may do so slightly; we can say only that they draw upon the vitality to maintain nerve-currents that give pleasure. It is agreeable to spend a certain portion of the forces of the system in nervous electricity; it is not agreeable to push this expenditure beyond a certain point. And when the stimulation has passed this point, degenerating into

either of them to the law that connects pleasure with an accession of vital power, and pain with depressed vitality. As regards my first law—called the law of Diffusion—both Mr. Spencer and Mr. Darwin have treated it under different phraseology, but in substantially the same way. It is the third of Mr. Darwin's three laws for explaining the phenomena of expression—termed by him the law of the "direct action of the excited nervous system."

Mr. Darwin furnishes incidentally many striking illustrations and confirmations of the law of pleasure and pain. Among the appearances of protracted grief, he remarks: "The circnlation becomes languid; the face pale; the muscles flaccid; the eyelids droop; the head hangs on the contracted chest; the lips, cheeks, and lower jaw all sink downward from their own weight." (p. 178.) Let any one compare this with the expression of a bride and bridegroom at the beginning of their honeymoon.

Mr. Darwin's second law, called by him the principle of Antithesis, occasionally leads him to exemplify the opposing efforts of pleasure and pain, as one of the varions forms of Antithesis, or the tendency to pass from one expression to its opposite, even although the opposing mental state wonld not generate that opposed expression. The principle of Opposition has been recognized in the text nnder two forms—first, the fnndamental law of pleasnre and Pain (self-conservation), and secondly, the employment of the small flexor muscles to complete the contraction of the powerfnl extensors, and secnre a more perfect attitude of repose and renunciation of nervous stimnlus.

The violent contortions of acnte pain are referred by Mr. Darwin to inherited habits of exertion for getting rid of pain. He wonld even regard the excited movements of animals nnder delight as partly associations with hnnting and the search for food; although he freely admits that the state of pleasure is itself accompanied with increased vigor of the circulation and the nerve-force.

pain, the pleasurable tone can be restored only by replenishing the vital power, according to the principle that connects pleasure with vitality.

I may remark, as confirming all that has been said, what is our common experience and practice with regard to pleasure, namely, the great value of the stimulants that are not intense but *voluminous*—that moderately affect a large sensitive surface, or many nerves at once: a familiar instance is furnished by the warm bath; another is the music of a full band. The same happy effect springs from change or variety; the stimulation is multiplied, and no one part pushed to exhaustion.

The last point that I will advert to is the obscure subject of narcotic stimulants—alcohol, tea, tobacco, opium, and the rest. These operate a very little way, if at all, in in giving new vitality; they draw upon our vitality, even till it is much below par, postponing the feeling of depression till another day. It is probable that the influence of the narcotics is complicated, and not the same for all. We may safely say respecting them, that they are the extreme instance of the principle of stimulation, as contrasted with the principle of vital conservation; they are the large consumers, not the producers, of vitality; they expend our stock of power in nerve-electricity in a higher degree, and with a more dangerous license, than the ordinary stimulants of the senses.

The physical theory of pleasure and pain has a direct bearing on punishment and prison discipline. I happened to be present at a debate on that subject, in one of the sections of the British Association, at the Manchester meeting in 1861. The speakers were bent upon suggesting modes of punishment, painfully deterring, and yet not injurious to the convict's health. I could not help remarking, from my conviction of the doctrine now expressed, that the object aimed at is all but a contradiction. There is, if any, the barest margin between the infliction of pain and the destruction of vital power. If the first of the two maxims above stated (the connection of pleasure with vital conservation, etc.) expressed the whole truth, there would be no margin at all: but under the second maxim (stimulation), there might be room to operate as proposed. Stimulants cannot, as a general rule, be said to increase vital power; they are usually on the verge of destroying it, and frequently do destroy it. Consequently, the *withholding of stimulation*—alcohol, tobacco, tea, cheerful light and spectacle, the sounds of busy life, society, amusing literature, etc.—cannot be said necessarily to abate the vital forces, and may be instrumental in conserving them. Nevertheless, if these are withheld to the extent of making them strongly craved for (and if they are not, their loss does not punish), the state of craving is an internal conflict that lowers the general vitality. If the craving dies away after a time, the depression ceases, and so does the punishment. Then, again, it might seem that the application of what is *painfully salubrious* would exactly hit the mark; as the cold bath, the well-ventilated and but moderately-heated cell, cleanliness, measured food, steady industry, and regularity of life. Yet unless the convict takes kindly to these various measures, they are more depressing than wholesome; and if his system does adapt itself, that is, if they end in reforming his constitution and habits, they are no longer punishment. In the debate in question, one of the speakers, who I believe was officially connected with a London prison, remarked that, as a rule, discharged convicts are deteriorated in constitution. The opposite allegation has sometimes been made; but between the two I will venture to arbitrate by saying that, in whatever cases the confinement operates as a serious punishment, the deterioration is almost certain. The same speaker observed that corporal punishment has this advantage over imprisonment—that, while it is a severe deterring smart, it does not to the same degree inflict permanent damage.*

THE WILL.

The will, volition, or voluntary action is, on the outside, a physical fact; animal muscle under nervous stimulation is one of the mechanical prime movers; the motive power of muscle is as purely physical as the motive power of steam; food is to the one what fuel is to the other. The distinguishing peculiarity of our voluntary movements is that they take their rise in feeling, and are guided by intellect; hence, so far as will is concerned,

* The two modes of punishing by physical torture are severe muscular strain (hard labor, the crank, tread-wheel) and flogging. The one operates upon the nerves through the muscular tissne, the other through the skin. There is no intention of injuring either the muscles or the skin in themselves; the sole object is to produce a painful condition of the nerves. Yet, as it is hardly possible, in severe punishments, to avoid permanent damage to the immediate tissue—muscle or skin—some plan might be devised for affecting the nerves alone. Recourse might be had to electricity. By electrical shocks and currents, and especially by Faraday's magneto-electric machine, which constantly breaks and renews the currents, any amount of torture might be inflicted; and the graduation might be made with scientific precision. How far the nerves would suffer permanent injury by a severe application of electricity is still a matter for inquiry; probably not more than by an equal amount of suffering through the muscular or skin punishments; while, at all events, the damage would be confined to the nervous tissue. The punishment would be less revolting to the spectator and the general public than floggings, while it would not be less awful to the criminal himself; the mystery of it would haunt the imagination, and there would be no conceivable attitude of alleviating endurance. The terrific power exercised by an operator, through the lightest finger touch, would make more deeply felt the hnmiliating prostration of the victim.

If capital punishments are to be permanently maintained, much could be said for discarding strangulation, and substituting an electric shock. But there being a growing opinion unfavorable to the extinction of life, as a mode of punishment, the combination of imprisonment with electric inflictions could be graduated to a severity of endurance that should satisfy all demands for retribntion to offenders. It was remarked by Lord Romilly that imprisonment with periodic floggings would be far worse than immediate execution. The idea would be too painful to the community at large; while a more refined application of pain would pass unheeded, except by the sufferer.

the problem of physical and mental concomitance is still a problem either of feeling or of intellect. The extension and improvement of our voluntary power is one large department of our education; and the process of education is wholly included under the intellect. I shall confine myself, then, as regards the will, to a short statement of the fundamental processes involved in it, one of which has just been before us under the feelings, and will again appear as playing a part in the intellect. In the will altogether I reckon up *three* elements; two primitive, instinctive, or primordial, and the third a process of education or acquirement.

The first primordial element is called the spontaneous energy or surplus activity of the system, or the disposition of the moving organs to come into operation of themselves previous to, and apart from, the stimulation of the senses or the feelings; the activity being increased when such stimulation concurs with the primitive spontaneity. I think there is evidence to show that the profuse activity attendant on health, nourishment, youth, and a peculiar temperament called the active temperament, springs in a very great degree from inherent active power, with no purpose at first but merely to expend itself, and that such activity gradually comes under the guidance of the feelings and purposes of the animal. It is the surplus nervous power of the system discharging itself without waiting for the promptings of sensation. In the course of education the spontaneity is so linked with our feelings as to be an instrument of our well-being, in promoting pleasures and removing pains. The voice by mere spontaneity sends forth sounds, the ear controls and directs them into melody, and the wants of the system generally make them useful in other ways.

Mere spontaneity, however, would not give us all that we find in the impulses of the will. Being the overflow of vital power, it would show itself only whenever and wherever there is such an overflow. We want a kind of activity that shall start forth at any time when pleasure is to be secured, or pain to be banished, and that shall be directed to the very points where these effects can be commanded.

For such a power we must refer to the great fundamental law of pleasure and pain —the law that connects pleasure with increase of vital power, pain with the diminution of vital power. This law we may look upon as in many respects the foundation, the mainstay of our being; it is the principle of self-conservation—the self-regulating, self-acting impulse of the animal system. When anyhow we come into a mood of joyful elation, the physical state corresponding is an exaltation of vital energy to the muscles, the organic functions, one or other, or both; and that exaltation is an increase of the activity that is bringing the pleasure. The first act of masticating a morsel of food develops a pleasurable feeling to the conscious mind, and a concurrent stimulus of heightened activity to the body; the heightened activity vents itself in the parts actually moving at the time—the masticating organs, the cheeks, jaw, and tongue, which in consequence proceed with redoubled vigor, the pleasure thus feeding itself. In that connection we have, as I believe, the deepest foundation of the will. On the other hand, if, in the course of energetic movements of mastication, a false step occurs, the teeth embracing by mistake the skin of the lip or the tongue, there is mentally a smart of pain, and physically, I think, a destruction of nervous power through the shock, and the destruction of power is at once and directly a cessation of the active current impelling the mouth and the jaws.

Such I conceive to be the groundwork of volition, greatly, but never entirely, overlaid in mature life by a large superstructure of acquired connections between feelings and specific movements. Without some such foundation I see no way of beginning the work of voluntary acquisition, nothing to make our movements relevant to our state of feeling at the time; moreover, it is the check that is always ready to step in and supersede our acquired habits. At any moment a burst of pleasure will raise our energies, a shock of pain (not being an acute exciting smart) will depress them; in the one case the cause of the pleasure, if our over-activity, will be maintained with increase; in the other case the energies are arrested, and if they are causing the pain, it will cease with them. The bursting out of a cheerful light in a dark labyrinth spurs us on without our going through the formality of what we call a resolution of the will; while a course leading us to darkness, strangeness, and uncertainty will be arrested by the mere sinking away of our energies before we can even begin to deliberate. Our course in life from first to last, although most at first, is trial and error, groping and feeling our way, acting somehow, and judging of the result; and the general tendency of the law in question is to sustain us when we are in a good track, to turn off the steam when we are in a bad track.

CHAPTER V.

THE INTELLECT.*

I NOW approach the most difficult part of the subject of the physical basis of mind—namely, what regards the intellect. That the feelings are closely connected with physical manifestations is patent and undeniable. But thought is at times so quiet, so far removed from bodily demonstrations, that we might suppose it conducted in a region of pure spirit, merely imparting its conclusions

* This chapter may not perhaps be easily understood by readers unfamiliar with the theory of our intellectual powers. It is not essential to the general argument; while it is more purely hypothetical and speculative than the foregoing chapter on the Feelings and the Will. The purpose of inserting it is to give completeness to the account of the most general laws of connection of mind and body, and to deal with what must ever be the most difficult problem growing out of that connection.

through a material intervention. Unfortunately for this supposition, the fact is now generally admitted, that thought exhausts the nervous substance, as surely as walking exhausts the muscles. Our physical framework is involved with thought no less decidedly than with feeling ; and it is requisite to define, if possible, the terms of the alliance.

In the positions already advanced, with respect to the feelings and the will, we have also some of the physiological foundations of thought.

The first position, named the Principle of Relativity, or the necessity of change in order to our being conscious, is the groundwork of thought, intellect, or knowledge, as well as of feeling. We know heat only in the transition from cold, and *vice versâ;* up and down, long and short, red and not red—are all so many transitions or changes of impression ; and without transition we have no knowledge. Relativity applied in this way to thought coincides with the power called *discrimination*—the sense or feeling of difference, which is one of the constituents of our intelligence. Our knowledge begins, as it were, with difference ; we do not know any one thing of itself, but only the difference between it and another thing ; the present sensation of heat is, in fact, a difference from the preceding cold.

The second position, named the Law of Diffusion—or the connection of feeling with spreading currents, as opposed to impulses that go the round in a single line—has bearings upon thought likewise. Taken along with the principle of relativity, or change of impression, it allows us, as we shall see presently, to embody the power of discrimination, or to assign its physical connections with the currents of the brain.

The third position had reference to the radical contrast of pleasure and pain, and was meant to bring out the connection between pleasure and a rise of vital power, and between pain and a fall of vital power. Although complicated with the fact that stimulus, as well as nourishment, is requisite to quicken the nerve-currents to the maximum of pleasure, this principle is a clear starting-point for our voluntary action, otherwise without a starting-point ; for the will mainly consists in following the lead of pleasure and drawing back from the touch of pain.

Our intelligence, in the *practical* view, may be considered as an enormous expansion of the range of operations under the first law of being — the law of self-conservation. To work for the attainment of pleasure while yet *in the distance*, and for the abatement of pain also in the distance ; to perform actions that are only *intermediate* in procuring the one or avoiding the other : all this is but voluntary action enlarged in its compass by knowledge of cause and effect, means and end ; in other words, by our intelligent cognizance of the order of the world.

Intellect has long been divided into a variety of functions, or modes of operating, called faculties, under such names as memory, reason, judgment, imagination, conception, and others ; which, however, are not fundamentally distinct processes, but merely different applications of the collective forces of the intelligence. We have no power of memory in radical separation from the power of reason or the power of imagination. The classification is tainted with the fault called, in logic, cross-division. The really fundamental separation of the powers of the intellect is into three facts called (1) *discrimination*, the sense, feeling, or consciousness of difference ; (2) *similarity*, the sense, feeling, or consciousness of agreement ; and (3) *retentiveness*, or the power of memory or acquisition. These three functions, however much they are mingled, and inseparably mingled, in our mental operations, are yet totally distinct properties, and each the groundwork of a different superstructure. As an ultimate analysis of the mental powers, their number cannot be increased or diminished ; fewer would not explain the facts, more are unnecessary. They are the intellect, the whole intellect, and nothing but the intellect.

Let us take them in order.

I. Discrimination. — This we have just seen is the intellectual aspect of relativity, or the law of change of impression. When any new currents are commenced, or when existing currents are increased or abated, we become mentally alive ; and if we are already conscious, a change comes over our consciousness. It can be easily made apparent that discrimination is the very beginning of our intellectual life. If we are insensible to the change from hot to cold we are forever disqualified from knowing the phenomenon of heat ; to be unaffected by changes of light is another way of expressing blindness ; to be affected, or made conscious, by very minute shades of color is to be highly intelligent in regard to color. Wherever a man is more knowing than his fellows, he sees distinctions where they see none. The banker detects a bad note after it has deceived many other people.

As to the physical embodiment of this fact : When we consider the vast compass of our discriminative sensibility—the seemingly innumerable shades of our consciousness in correspondence with the variety of sensible appearances, not to speak of our emotions and inner life — we begin to be aware of the need of an apparatus of great range and complication. Take any of the senses, as sight, and consider all the degrees that we can mark between total blackness and the highest solar refulgence. Consider next the colors and their shades, and we shall find that the sensible gradations of effect are very numerous ; in a mind highly endowed for color, these felt gradations would be counted by hundreds. Again, in the ear, a musician's discrimination of *pitch* extends, perhaps, to several hundred sounds. Our discrimination of *articulate* sounds is co-extensive with the combined alphabets of all the languages known to us.

Assuming, as we have found reason to do,

that every new impression on the sense is an alteration of the currents along the track of the nerves—both the main channel and the collaterals of the diffusion—we are led to believe that consciousness is varied in two ways. First, *according to the ingress made use of*, or the particular organ and the particular nerves employed. Thus, from the eye to the ear is a perceptible transition and a new phase of consciousness. So in touch, in taste, and smell, we have a characteristic consciousness for each sense through all the varieties of sensation of that sense. We should never confound a color with a taste. Nay, more: in the higher senses, and especially in sight and in touch, we have differences of consciousness according to the *part* of the organ affected; if it were not so, we should all be in the proverbial position of not knowing the right hand from the left.

In the second place, consciousness is obviously varied according to the *energy, or other peculiarity, of the impression* made on the same organ, or part of an organ, and the same nerve. A greater impression makes a greater feeling. This of course is what we are prepared for on any hypothesis. The currents are made more intense, and a change of nervous intensity is a change of consciousness. In the senses, however, we have *qualitative* differences of sensation, which are more embarrassing to account for. To define the change of current in the optic fibres by red, yellow, and blue, and the subsequent course of diffusion, is not within our present knowledge. It has been supposed that there are separate fibres for the primitive colors, which would somewhat relieve the difficulty, and reduce the different modes of action to mere differences of intensity or degree.

These two circumstances, namely, the separate consciousness of separate nerves, and the changing intensity of the currents, we may regard as the primitive modes of diversifying the consciousness; but it is in the countless combinations of these simple elements that we are to look for the physical concomitants of our ever-varying consciousness. The union of different stimulations in different fibres and in different degrees, would unavoidably give birth to a complex and modified consciousness.

II. So much for discrimination. Let us now glance shortly at similarity, or AGREEMENT. Besides the shock of difference, or change, the mind is affected by the shock of agreement in the midst of difference. If a certain sensation, as redness, is felt, and if, after we have passed to something else, it recurs, there is a flash of recognition, a reinstatement of the first experience together with a feeling of recognition or identification. This is the feeling or consciousness of agreement; it also is a great intellectual foundation. Coupled with discrimination, it exhausts the meaning of what we call knowledge; to know anything, as a tree, is to discriminate it from all differing objects, and identify it with all agreeing objects. The extension of our knowledge of the tree is the extension of our sense of its differences and of its agreements. Similarity, in another view, is a great power of reproducing our past experience and acquisitions, an extension of the resources of memory. By it, principally, we "ascend the brightest heaven of invention." We are perpetually reminded of objects by the presence of something of a resembling kind. Looking at a cathedral, we readily bring to mind other cathedrals; hearing an anecdote, we are almost sure to recall some one similar. Our reason essentially consists in using an old fact in new circumstances, through the power of discerning the agreement; we have sown one field and seen it grow, and we repeat the process in another field. All this is a vast saving of the labor of acquisition; a reduction of the number of original growths requisite for our education. When we have anything new to learn, as a new piece of music, or a new proposition in Euclid, we fall back upon our previously formed combinations, musical or geometrical, so far as they will apply, and merely tack certain of them together in correspondence with the new case. The method of acquiring by patchwork sets in early, and predominates increasingly.

III. I might go on to apply the views respecting the cerebral structure and workings, in divining the physical process underlying this power of similarity; but we shall be still better occupied in grappling with the remaining intellectual function, RETENTIVENESS, or memory, whose explanation would make all the rest easy enough.

It is related by the younger Scaliger that two subjects especially engaged the speculative curiosity of his father, the celebrated Julius Cæsar Scaliger; these were, the cause of memory and the cause of gravity. With regard to the last-named of the two—the nature of gravity—we have, since the Newtonian discovery, learned to consider that as a solved problem, and a good example of what constitutes finality in scientific inquiries: namely, when we have generalized a natural connection to the utmost, ascertained its precise law, and traced its consequences. That matter gravitates—that the property called inertia, or resistance, is united with the separate property of attraction at all distances, we accept as a fact, and, unless indeed we saw our way to generalizing it one step farther, we ask no more questions. So in the subject before us. There are two very distinct natural phenomena, the one we call consciousness or mind; the other we call matter and material arrangements; they are united in the most intimate alliance. It is for us to study the nature of each in its own way, to determine the most general laws of the alliance, and to follow them out into the explanation of the facts in detail; and then, as with gravity, to rest and be thankful.

The great scholar might, however, be forgiven for wondering at memory. There is nothing marvellous in nature's having allied this and the other mental functions with a

bodily organization; for unless it be that the facts called MIND and the facts called MATERIAL are the most *widely contrasted* facts of our experience, and that we have, as it were, a meeting of *extremes*, there is no more mystery in this union than in the union of inertia and gravity, heat and light. It is because we have something beyond the usual endowments of natural things, in the possibility of storing up in three pounds' weight of a fatty and albuminous tissue done into fine threads and corpuscles, all these complicated groupings that make our natural and acquired aptitudes and all our knowledge. If there were sermons in stones, we should be less astonished when they proceed from brains.

Retention, acquisition, or memory, then, being the power of continuing in the mind impressions that are no longer stimulated by the original agent, and of recalling them at after-times by purely mental forces, I shall remark first on the cerebral seat of those renewed impressions. It must be considered as almost beyond a doubt that "*the renewed feeling occupies the very same parts, and in the same manner as the original feeling*, and no other parts, nor in any other manner that can be assigned."

This view is the only one compatible with our present knowledge of the working of the nerves, although there formerly prevailed and still prevail other views: the doctrine of a common sensorium or cerebral closet where ideas are accumulated, quite apart from the recipient apparatus. But that view is so crude as hardly to merit discussion. If we suppose the sound of a bell striking the ear, and then ceasing, there is a certain continuing impression of a feebler kind, the idea or memory of the note of the bell; and it would take some very good reason to deter us from the obvious inference that the continuing impression is the persisting (although reduced) nerve-currents aroused by the original shock. And if that be so with ideas surviving their originals, the same is likely to be the case with ideas resuscitated from the past—the remembrance of a former sound of the bell. All observation confirms the doctrine. The mental recollection of language is a suppressed articulation, ready to burst into speech. When the thought of an action excites us very much, we can hardly avoid the actual repetition, so completely are all the nervous circuits repossessed with the original currents of force. The lively remembrance of a pleasant relish will produce the same expression of countenance, the very smack of the reality. Moreover, it has been determined by experiment that the persistent imagination of a bright color fatigues the nerves of sight.*

The comparative feebleness of remembered states or ideas is, we may presume, an exact counterpart of the diminished force of the revived currents of the brain. It is but seldom that the reinduced currents are equal in energy to those of direct stimulation at first hand.

And now, as to the mechanism of RETENTION.

For every act of memory, every exercise of bodily aptitude, every habit, recollection, train of ideas, there is a specific grouping, or co-ordination, of sensations and movements, by virtue of specific growths in the cell junctions.

For example, when I see a written word and, as a result of my education, pronounce it orally, the power lies in a series of definite groupings or connections of nerve-currents in the nerve and centres of the eye, with currents in motor nerves proceeding to the chest, larnyx, and mouth; and these groupings or connections are effected by definite growths at certain proper or convenient cell crossings.

The considerations that support us in hazarding this proposition are such as the following:

In the first place, it is merely stating the mode of action appropriate to the structure and known workings of the brain. If the brain is a vast network of communication between sense and movement—actual and ideal—between sense and sense, movement and movement, by innumerable conducting fibres, crossing at innumerable points—the way to make one definite set of currents induce a second definite set is in some way or other to strengthen the special points of junction where the two sets are most readily connected, so that a preference shall be established, and in that particular line of communication. The special growths accompanying memory must operate at these cell or corpuscle junctions.

Our mode of conceiving the so-called reflex actions illustrates what I mean. A stimulus proceeds along a given nerve to a central point—a group of cells; and there is a defi

* Great consequences follow (as it seems to me) from this view of the physical embodiment of intellect. There grows out of it a tendency of ideas to become the full reality; as when a person strongly imagining a kick, can scarcely refrain from the performance. The comparative weakness of the nerve-currents accompanying the idea, and the superior force of present realities, render the manifestation unfrequent in waking hours, and under ordinary conditions. Any circumstances, on the one hand, tending to intensify the idea, or, on the other hand, removing the pressure of the actual, exhibit the influence in full operation. The mesmeric sleep is the extreme instance; the ideas suggested to the mind of the patient exclusively determine his conduct.

No fact of the human constitution more decisively proves the connection of intellect with the nervous system and with the moving organs and the senses. The intimacy of the alliance is shown at its utmost.

This principle is a supplementary law of the will; it is a stimulus to action, over and above the primary and proper motives of the will (pleasure and pain), and often leads to conduct at variance with our interests as represented by procuring pleasure and warding off pain. A complication of the principle has been greatly discussed of late, under the designation of the "power of the imagination over the body;" according to which ideas can induce healthy and morbid changes on the system. By thinking strongly on the hand, we affect the local circulation of the blood, and by persistent attention we might set up a diseased action in the part. Applications of this peculiar effect have been suggested in medicine, and the conditions and limitations of it are deserving of careful study. It has been happily made use of by Mr. Darwin to explain blushing.

nite response to a certain movement, as in the closed hand of the sleeper. Now the higher connections of mind are of the same essential character, though far surpassing in complication; the system of freely diffused lines of communication in the brain is an obstacle to that ready selection of an outgoing channel; and there is at first much conflict and distraction, until circumstances shall determine preference outlets and until structural growths confirm these preferences.

The position is also fortified by the effect of diseased points in the brain which are known to destroy memory, often sweeping away some definite class of acquisitions or recollections, and leaving others untouched. We have now on record many remarkable cases of the destruction of the second and third frontal convolutions of the brain accompanied by loss of speech, while the intellectual faculties generally were unimpaired.

In the next place, acquisition has a limit determined by the amount of the nervous substance, that is, the size of the brain.

We are apt to be carried away with a vague notion that there is no limit to acquirement, except our defect of application or some other curable weakness of our own. There are, however, very manifest limits. We are all blockheads in something; some of us fail in mechanical aptitude, some in music, some in languages, some in science. Memory, in one of these lines of incapacity, is a rope of sand; there must be in each case a deficiency of cerebral substance for that class of connections.

Then, again, there is a tendency in acquisitions to decay unless renewed. Hence, a time must come in the progress of acquisition when the whole available force of growth is needed in order to conserve what we have already got; when, in fact, we are losing at one end as much as we gain at the other.

It is further to be remarked that much of our mental improvement in later life is the *substitution* of a better class of judgments for our first immature notions, these last being gradually dropped. There is not necessarily more room occupied in the brain by a good opinion than by a bad, when once the good opinion is arrived at; or by an elegant gesture as compared with an awkward one.

Even taking the regular student, whose life is spent in amassing knowledge, we find that his memory at last, if it does not refuse the new burdens, gives them place by letting go much that has been previously learned. Moreover, a wide scholarship turns into a knowledge of the places where knowledge is. It is only a limited range of ideas that any one can command at any one time; although in the course of a life we may shift into several successive spheres of intellectual range.

Further, we have seen, in alluding to the power of similarity or agreement, that one acquisition is made to serve on many different occasions. A new word is a group of old articulations; a new air to a musician, a new manipulation to a chemist, is merely a slight variation of some previous acquirement.

Once more. In a vast number of instances, what we retain is not so much certain ready-made combinations, as the means for putting these together when required. This is well exemplified in the economy of names. By means of combining generic and specific names, two or three thousand words can suffice to name one hundred thousand plants. So in ordinary language: the suffix "ness," understood once for all, enables us to convert thirteen hundred adjectives into abstract nouns; so that the recollection of these abstract nouns involves no independent effort. And, in like manner, instead of having in the memory trains of formed sentences for every occasion, we have a certain number of forms that can be freely accommodated to the matter we wish to express.

And finally, the great principle of the will is, by its nature, self-correcting, after trial and error. This comes in place of many nice adjustments, and renders a sentient framework superior to all other machines. It is not necessary to the power of imitation that a sound heard should at once suggest the exact vocal articulation for reproducing the effect: something may be at first suggested not quite up to the sound: the sense of discrepancy then checks it; other movements arise and are likewise checked; and so on till the coincidence is reached.

I will now venture upon a hypothetical comparison between these two things—our acquisitions on the one hand, and the number of the nervous elements of the brain on the other.

A certain number of definite groupings or co-ordinations must be allowed to our various instincts; as, for example, the combined movements of the heart, intestines, and lungs, and the special modifications of them in swallowing, coughing, and sucking. The simplicity and the limitation of these acts are such as to require comparatively few pre-established groupings. When to the simple instincts of organic life we add the *higher instincts* included in our feelings, and their embodiment in our voluntary powers, and even in our intelligence, the number is enlarged on a scale corresponding with the acquired aptitudes; and the new theory is that these higher instincts are all hereditary, or transmitted acquisitions.

Our acquisitions taken as a whole represent the great mass of our nervous growths. I shall attempt to give a rough classification of them:

1. The simpler and earlier voluntary aptitudes, implied in the voluntary control of the various moving members, as the hand. We have not originally the power of moving any part in a definite way to execute a purpose; we have to associate the several movements with the effects to be produced. With the sight of a morsel of food, and the state to hunger, we associate the definite movement of the hand to the mouth. With the feeling of a morsel in the mouth, we have to associate

definite movements of the tongue and the jaw. These are groupings of a considerable degree of complication. A visible image, with the knowledge of what the vision suggests, as, for example, a bit of sugar, and a feeling or craving based on a recollection of the past—concur as a definite situation; and that situation has to be followed by a grasping movement of the hand, and a subsequent movement toward the mouth; to which succeeds a series of movements in the mouth itself. The exercise of the voluntary powers is a manifold repetition of the same fact—a definite situation followed by a definite group or series of movements.

2. The muscular groupings in the various experiences of resistance, size, form, and allied properties. These are embodied in the hand, the arm, and the locomotive organs generally, and in the allied nervous centres for motor currents. Without the special senses, as sight, these notions are very vague, showing that the provision for the nervous embodiment of movements is not great. Still we can discriminate degrees of force, by the muscles alone; to every distinguishable degree there must be a definite and distinct nervous track; and to every association with each special degree, there must correspond an appropriate nervous grouping, disentangled from all other groupings. With every distinguishable weight we form some separate associations, some actions to be performed when that weight is felt, as in sorting, according to weight, heavy and light things.

The groupings in the muscles of the eye that correspond to visible motions and forms are exceedingly numerous. These enter into our highest intellectual acquirements of visible pictures and arrangements. A circle is a series of ocular movements, in definite march and grouping; for this one effect hundreds of currents are excited in individual fibres and cells.

The groupings of the larynx, tongue, and mouth, for vocal exertions, and above all for articulate speech, are on a vast scale. As with every simple form visible to the eye, so with every separate articulate sound—every letter in the alphabet—there is a complex series of situations, graduated and organized in the corresponding centres, whether pure motor, or motor and sensory combined.

3. Although there is a propriety in viewing the muscular associations as a distinct branch of our mental framework, they are, in point of fact, always blended with the special senses; and the delicacy of discrimination is far higher in the pure and proper senses than in the muscles alone. By the pure senses are meant, touch (without strain or pressure), taste, smell, hearing, sight (in its optical part). To every discriminated sensation there is (we must believe) a distinct and characteristic group of currents, actuating a separate group of fibres and cells, and susceptible of being united with any definite movement or any other definite sensation. Now even in the inferior senses, the grades of discrimination are numerous; in taste and smell, probably hundreds; in hearing and sight, thousands. In the quality of musical pitch, a fine ear can discriminate a small fraction of a tone; in a range of seven octaves a great many separate sensations could be held apart without being confounded. If to pitch we add intensity, volume, and timbre, the discriminations would be multiplied in proportion. Still, however, the discriminations held in the memory are not so numerous as we might suppose from the delicacy of comparing the *actual* sensations.

The eye, by its optical function, takes in grades of light and shade, mixtures of white and dark in the series of grays, and varieties of color. A good eye might have several hundreds of distinct optical gradations in these various effects. But the eye shows its great compass in the plurality of combinations of points or surfaces of different light, making up what are commonly called *images:* compounds of visible form (muscular) and visible groupings (optical). The multitude of these that can be distinctly embodied and remembered would seem to defy computation; yet every one must have its own track in that labyrinth of fibres and corpuscles called the brain.

4. Thus, in the muscular feelings, and in the sensations of the special senses, there are all these various grades of distinguishable states of feeling, and an enormous number of connections between them in our memory of things and of events. Yet further. Movements may be associated with sensations in every one of the senses; and there may be associations between each sense and all the others: Touches, with tastes, smells, sounds, sights; tastes, with smells, sounds, and sights; smells, with sounds and sights; and, most of all, sounds with sights. What we call our knowledge of a thing is the union of all the sensations produced by it into a complex idea of that thing. The idea of a shilling is a compound of visible appearance, sound, and touch.

5. All these simpler combinations are themselves re-compounded into still higher combinations. The far-reaching and all-embracing acquisition, called language, is based on the articulate groupings; these are formed into words, words into phrases and sentences; and all the while there is a process of adhesion between each verbal element and some object of sight or other sense. The vocal articulation in uttering the word "sun," the sound it makes on the ear when pronounced, the appearance of the thing—are all united, in one higher grouping or complex intellectual product. Words are thus joined to things; trains of words are joined to trains of events. In learning foreign languages, words as sounds are joined to other words as sounds, visible symbols to visible symbols; trains of words in both capacities to other trains. As we can readily compute the number of words making up the vocabulary of a language, we have a means of setting forth in a sort of numerical estimate

the extent of our acquisitions, and the number of independent brain-growths that correspond to these.

Every *special acquirement* is a re-compounding of the elementary groupings above sketched. A science, for example, such as arithmetic, is a vast aggregate of new sensible groupings ; the elements being our notions of number gained from numbered things, the ten ciphers, and their union in the decimal system. There is here a great process of economy. The multiplication table, which contains 144 propositions, or statements of the equivalence of numbers, is a weapon of indefinite power in computation. Still a great deal of independent acquisition must succeed these embodiments of the multiplication table ; many further rules must be learned, with exemplifying instances. To work vulgar and decimal fractions demands the forming of new and complicated ties. Conceive, then, the amount of distinctive nervous embodiment in one arithmetical fact, as "six times ten is sixty ;" one hundred and forty-four such are needed for the table ; while the table itself is really a very small portion of the growths in the mind of a fair arithmetician, even allowing for the process, so abundantly exemplified in science, of making the old serve in the new. Supposing the table were one fiftieth of the memorial embodiment of any one's arithmetical powers ; the nervous growths would be upward of seven thousand for this one subject. Five more sciences of like compass would give more than forty thousand groupings ; but there would be a very great condensation through unavoidable repetitions. Still an accomplished mathematician might have upward of twenty or thirty thousand groupings of the degree of complicacy typified in the table ; there being, however, a considerable number of trains equal in length to several columns of the table.

In learning an air of music, suppose the "Old Hundredth" psalm tune, there is a definite succession of notes. We may view the embodiment of such an acquisition in this way. The first note suggests nothing ; three or four are needed to determine the air. With the sequence of, say, four notes, is associated the fifth, and at the same time the name and all other adjuncts of the air. A complex situation is thereby created, and with that the succeeding notes are all associated in train. About thirty notes are thus enchained in a fixed order ; each note being the associated sequel of a group of notes, or other mental effects, of at least three or four members There are thus nearly thirty associations of some complicacy in this single air. A good musician has hundreds of such sequences ; perhaps upward of a thousand, but not less than a thousand. Great allowance must be made for repetitions. A musical education would thus comprise as many as twenty thousand separate associations of small determining groups of notes with other notes.

It is on this analogy that we should have to express the verbal memory for consecutive statements. The determining words of a passage—two, three, or four in number—will commence the train ; every new word is associated with a prior group of words and meanings.

6. In the acquired connections with the feelings or emotions, and in those associations of will called the "moral habits," we might exemplify a distinct and somewhat peculiar class of growths. The number is still very great ; as is apparent when we reflect upon the great multitude of things connected in our mind with pleasurable and painful feelings. The peculiarity lies in the greater impetus or power in every wave that involves either feeling or an exercise of will. To this impetus must correspond a burst of nervous power, and for that burst we seem to need a certain mass of nervous substance—a large body of corpuscles roused into activity. Think of the strain necessary to maintain a struggle of the will against a strong present appetite. In such a case as this the corpuscles of the brain must not act solely as junctions for establishing complicated groupings, but as sources of energy ; and they need to be multiplied in that view. Size of brain, or multitude of nerve-elements—fibres and corpuscles—does not follow intellect alone, but varies with the need of motive muscular power ; to which we must now add energy of emotional manifestations and of will or volitional impulses. Accordingly, a considerable share of the nervous elements has to be assigned to the class of growths now mentioned.

There is a nice question raised, as to whether the three functions—intellect, emotion or feeling, and will, are *separately located* in the brain. The likelihood is that intellectual combinations and feelings go together ; with this difference, that the currents of feelings or emotions have a wider diffusion and more forcible impetus, and find their way to the motor centres at large, evoking what is called the expression of feeling. The primitive shocks of feeling are at once intellectual and emotional, but may afterward be developed more in the one direction than in the other ; yet every intellectual exertion has an emotional side, every emotional outburst an intellectual side.

The association of objects with feelings is an immense power in the mind ; it governs very largely the pleasurable and painful susceptibilities of mature life. According to the doctrine of evolution, this class of growths becomes hereditary, and accounts for our special emotions, as fear, love, and anger.

Let us put together these and other indications of the extent of the human acquisitions demanding separate and independent nervous embodiments. Take the case of learning languages, where the numerical estimate is approximately attainable. We can count the number of words in a language ; we can make allowance for the repetition of the same root-word in different compounds. The association of a word with a simple

meaning, as sun, fire, hill, food, presents a limited, though still considerable, degree of complication. The association of one name with another in a foreign tongue is a still simpler conjunction.

I may cite as an illustration the Chinese language, with its forty thousand characters. The strongest memory is incapable of retaining these: indeed a very unusual stretch of memory is requisite to keep hold of the ten thousand need for the ordinary literature.

Again, consider the situation of a philologist knowing six cultivated languages and ten uncultivated vocabularies (of several hundred vocables each). Such an acquirement would use up little less than half the attention and plasticity of one's life. If, then, this education were represented by fifty thousand cerebral connections, of variable complication, but many of them very simple, as word to word, we could assign a rough valuation to the magnitude of our possible acquisitions.

The rival department to language, as regards variety and amount, is the department of visual recollections, or pictorial groupings and spectacle. Here, too, we reach a limit. A datum for calculation might be, how many faces could we remember and associate with names and other accompaniments? Not certainly more than two or three thousand. So with the remembrance of localities, as the streets of towns. A life would not suffice for laying up in the memory the streets of London.

Such an object as the human face and figure might seem an enormous complication. Every feature has its form, size, and coloring; and the comprehension of such an aggregate would appear to demand an immense aggregate of sense impressions, and use up a very large area of nervous connections. This complication, however, is delusive. The memory does not retain a colored photograph, but only a few salient and deciding marks; perhaps not more than from six to ten indications of form, size, and color. These are enough for identification, and we do not retain any more, except in cases of very peculiar intimacy.

A naturalist, with all the aids of classification, cannot retain in his memory the marks of more than perhaps two or three thousand species; for the rest he must be content to refer to his books. Yet he, too, must have devoted the larger half of the plastic energy of his brain to his special studies.

The conclusion is that the cerebral growths of a certain typical complication cannot be adequately stated in hundreds; they amount to thousands, and even tens of thousands; they scarcely count by hundreds of thousands.

Let us make a rough estimate of the nervous elements—fibres and corpuscles—with a view to compare the number of these with the number of our acquisitions.

The thin cake of gray substance surrounding the hemispheres of the brain, and extended into many doublings by the furrowed or convoluted structure, is somewhat difficult to measure. It has been estimated at upward of 300 square inches, or as nearly equal to a square surface of 18 inches in the side. Its thickness is variable, but, on an average, it may be stated at one tenth of an inch. It is the largest accumulation of gray matter in the body. It is made up of several layers of gray substance divided by layers of white substance. The gray substance is a nearly compact mass of corpuscles, of variable size. The large caudate nerve-cells are mingled with very small corpuscles, less than the thousandth of an inch in diameter. Allowing for intervals, we may suppose that a linear row of five hundred cells occupies an inch; thus giving a quarter of a million to the square inch, for 300 inches. If one half of the thickness of the layer is made up of fibres, the corpuscles or cells, taken by themselves, would be a mass one twentieth of an inch thick, say sixteen cells in the depth. Multiplying these numbers together, we should reach a total of twelve hundred millions of cells in the gray covering of the hemispheres. As every cell is united with at least two fibres, often many more, we may multiply this number by four, for the number of connecting fibres attached to the mass, which gives four thousand eight hundred millions of fibres. Assume the respective numbers to be (corpuscles) one thousand, and (fibres) five thousand, millions, and make the comparison with our acquisitions as follows:

With a total of 50,000 acquisitions, evenly spread over the whole of the hemispheres, there would be for each nervous grouping at the rate of 20,000 cells and 100,000 fibres.

With a total of 200,000 acquisitions of the assumed types, which would certainly include the most retentive and most richly-endowed minds, there would be for each nervous grouping 5000 cells and 25,000 fibres.

This leaves out of account a very considerable mass of nervous matter in the spinal cord, medulla oblongata, cerebellum, and the lesser gray centres of the brain; in all of which there are very large deposits of gray matter, with communicating white fibres to match.

Such an estimate, confined to the hemispheres of the brain, is enough for its purpose, which is to show that numerous as are the embodiments to be provided for, the nervous elements are on a corresponding scale, and that there is no improbability in supposing an independent nervous track for each separate acquisition.

It is not at all likely, however, that the entire brain can be partitioned equally among the various subjects to be remembered or acquired. Besides the fact that a great part of the brain substance exists for mere battery power—to propel muscles, and to keep up energetic volitions and manifestations of feeling—there seems often to be a duplication of the same embodiment in different parts. The two hemispheres apparently repeat one another; when one is injured, the other keeps up the trains of memory, although

with weakened energies. It is even supposed that in the same hemisphere there my be duplicates ; since injuries in the forepart of the head have occurred without destroying any single class of acquisitions. Moreover, it is most unlikely that a perfect economy of the cells and fibres can be realized, however well distributed the acquisitions may be. Could we bring all the elements into full play, there might possibly be room for many times our present average store of recollections.

We may go one step farther, and inquire how the various groupings may arise, and how they can be isolated so as to preserve the requisite distinctness in our trains of thought. Let me first call attention to the difficulties of the case.

If each set of sensory fibres had one definite connection with motory or outcarrying fibres, we should have always the same movement answering to the stimulation of the same nerves, as in the reflex system ; the fibre *a* could do nothing but effect the movement *x*. It is necessary to the variety and flexibility of our acquirements that the fibre *a* should at one time take part in stimulating *x*, and at another time take part in stimulating *y*, the circumstances being different. The stroke of the clock will stimulate us at one time to set out in one direction, and at another time in another direction, according to the ideas that *it co-operates with*. Then, again, the *degree* of the stimulation of the same fibres will determine, not merely a greater energy of the same response, as would happen in reflex stimulation, but a totally different response : *a*, *weak*, determines movement *x ; a*, *strong*, determines *y* The steersman of a ship making for port is guided by the intensity of the beacon light.

These illustrations show the two chief conditions whereby the same nerve is instrumental in causing distinct movements, namely,

1st. Its being differently grouped.

2d. Its being unequally stimulated.

We shall begin with the case of *difference of grouping*. The fibre *a* stimulated along with *b* gives *x ;* so *a c* gives *y*, and *b c* gives *z*.

Let us try and imagine how the structure is adapted to this state of things. It requires us to assume, not merely fibres multiplying by ramification through the cell junctions, but also an extensive arrangement of *cross connections*. We can typify it in this way. Suppose *a* enters a cell junction, and is replaced by several branches, *a'*, *a'*, etc. ; *b*, in like manner, is multiplied into *b'*, *b'*, etc. Let one of the branches of *a*, or *a'*, pass into some second cell, and a branch of *b*, or *b'*, pass into the same, and let one of the emerging branches be *X*, we have then a means for connecting united *a* and *b* with *X ;* and, in some other crossing, a branch of *a* may unite with a branch of *c*, from which crossing *Y* emerges, and so on. In every case of united stimulation producing a definite movement, we must suppose a set of cells where ramifications of the stimulated nerves unite themselves, and find an outlet of communication with that special movement.

The diagram shows the arrangement. The fibre *a* branches into two *a'*, *a' ;* the fibre *b*, into *b'*, *b' ; c*, into *c'*, *c'*. One of the branches of *a* unites with one of the branches of *b*, or *a' b'* in a cell *X ; b' c'* unite in *Y ; a' c'* in *Z*. These cells *X*, *Y*, *Z*, are supposed to be the commencement of motor fibres, each communicating with a separate muscular group, and rousing a distinctive movement. By this plan we comply with the primary condition of assigning a separate outcome to every different combination of sensory impressions.

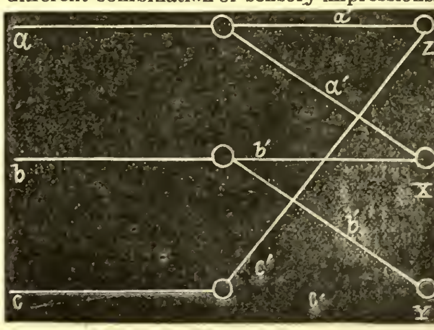

FIG. 2.

We may compare this diagram with the following, given by Dr. Lionel Beale, to show the manner of junction of nerve-fibres with caudate nerve-cells. The crossing of fibres from one cell to collateral cells is exactly what is supposed in the foregoing representation. Dr. Beale is not advocating any theory of the physical basis of our intellectual acquisitions ; his object is to represent the connections of fibres and corpuscles as actually exhibited. The conformity of his diagram with the scheme of cross connections required by the foregoing hypothetical scheme, is very striking. But, indeed, without a most extensive system of these lateral communications, we should be wholly unable to imagine the embodiment of our distinctive mental impressions.

We have taken the simplest case possible —binary groupings of three elements, *a*, *b*, *c*. The diagram shows that for these we need three primary fibres, six branching fibres, and six cells. Our acquisitions involve far more complex groupings. To give a distinctive character to the most ordinary impression on the eye, or the ear, there is commonly a union of four, five, six, seven, or more, separate impressions, as in the letters of a word, the characters of a piece of furniture, the marks of an individual person ; and each of these elementary or constituent impressions—a letter of the alphabet, a round or square form—is already a complex compound. Hence the number of fibres and cells brought into action, before the grouping can converge upon some one set of cells definitely connected with an out-going motor arrangement, or with some other internal grouping—must be very great indeed ; and but for the vast number of fibres and cells, demonstrably present in the brain, the sepa-

FIG. 3.

rate embodiment of every separate impression and idea would seem impracticable.

Next as to *unequal intensities* of stimulation of the same nerves : *a*, weak, is connected with *X; a*, stronger, with *Y; a*, still stronger, with *Z*. When you taste a cup of tea, you give utterance to the word "weak" under one pitch of sensation ; at another pitch, the same nerves being affected, you give forth the word "good." On a fine ear the same fibres may discriminate many shades of intensity, and may for every one be associated differently with vocal exertions. Now, a more energetic current necessarily takes *a more extended sweep*, and affects a number of cells and fibres that are left quiescent under a feebler current. The cells being viewed as *crossings*—where a current in one circuit induces a current in an adjoining circuit—there is, at each crossing, a certain resistance to overcome, and the feebler current is sooner exhausted and stops short of the distance reached by stronger. It is like a larger wave on the sea-shore, whose superior bulk and impetus are made most conspicuous by outstripping all the rest as it rushes up the sands. We may figure the action thus :

A certain intensity makes an effective induction (in the electrical sense of the word "induction"), suppose once ; the currents so generated do not produce a second induction of the same power. A weak current in a certain line of fibres produces, we shall say, a hundred *secondary* currents, which amount of diffusion gives to it its character in the consciousness, and its local habitation where it meets outgoing motor currents. But a stronger impetus will determine all these hundred secondary currents, and a hundred *tertiary* besides, which will make the character of its diffusion ; and the points where a number of the secondary concur with a number of the tertiary will be the points where a definite motor current may be associated with it. So that what begins as mere difference of intensity in one track ends in difference of grouping, or in characteristic points of meeting, whence a definite motor current may take its rise, and be distinctively united.

Having thus considered how to provide, for every new mental connection demanded for our progressive acquirements, a special nervous track devoted to that connection, the remaining point is to consider by what means the connections are permanently fixed in the several tracks. This is to assign the physical bond underlying memory, recollection, or the retentive power of the mind.

We know what are the conditions of making an acquirement, or of fixing two or more things together in the memory. The separate impressions must be made together, or flow in close succession ; and they must be held together for a certain length of time, either on one occasion, or on repeated occasions. Now to each impression, each sensation or thought, there corresponds physically a group or series of nerve-currents ; when two impressions concur, or closely succeed one another, the nerve-currents find some bridge or place of continuity, better or worse, according to the abundance of nerve-matter available for the transition. In the cells or corpuscles where the currents meet and join, there is, in consequence of the meeting, a *strengthened connection* or *diminished obstruction*—a preference track for that line over other lines where no continuity has been established.

This is merely a hypothetical rendering of the facts : yet it is a very probable rendering. In the nature and number of the nerve elements, and their mode of connection, there is nothing hypothetical ; and there is no departure from fact or strong probability, in assigning special and distinct tracks for the currents connected with each separate sensation, idea, emotion, or other conscious state. As to the precise mode of the plastic growth that unites separate impressions into trains and aggregates in the memory — we know that the corpuscles or crossings are the points that must be operated upon ; that a flow of healthy blood must co-operate to the effect ; and that the process takes time. It is evidently a species of growth : but the precise molecular change effected in the lines of strengthened communication, or diminished obstruction, we can describe only as increasing the conducting tendency in those lines, as compared with the collateral openings where no such operation has taken place.*

* In thus endeavoring to sketch the embodiment of our intellectual functions in the cerebral system, I have been very much aided by the views and the diagrams of Dr. Lionel Beale. Almost every one of the views peculiar to him assist the foregoing speculation.

1. As regards the connection of the nerve-cells, Dr. Beale maintains that all true nerve-cells are continuous with nerve-fibres, and have at least two such connections. The so-called *apolar* cells—having no visible communications with fibres—are without meaning on any hypothesis of nervous action hitherto suggested. Moreover, while it is admitted that there may be as few as two nerve connections, a large proportion of cells must have more than two, otherwise nerve-fibres would have to rise in the brain as loose ends.

2. With respect to the minuteness, and consequently the number, of the ultimate nerve-fibres, Dr. Beale supposes that the so-called ultimate fibre (the dark-bordered fibre, varying from 1-3000th to 1-15000th of an inch) may be in reality a bundle, and that the true ultimate fibres are represented by the terminal ramifying fibres of 1-100,000th of an inch, or less. Now upon the supposition of a distinct nervous track, or series of connections, for each distinct acquirement, the number of the fibres must correspond to the number of acquirements ; and the greater the number actually proved to exist, the more credible is the

CHAPTER VI.

HOW ARE MIND AND BODY UNITED?

A VAST deal of speculation has been expended as to the manner of union of mind and body. The majority of persons are disposed to treat the question as insoluble, as unsuited to our faculties, as what is termed a "mystery."

This word "mystery" is itself greatly misconceived. Such was the opinion of one of the ablest of biblical critics—Principal George Campbell—as to the employment of the word in religious doctrine. In Campbell's view "μυστήριον" means simply what we call a secret—a thing for the time concealed, but afterward to be made known. It is the correlative term to "revelation," which disclosed what had previously been hidden.

In another acceptation, mystery is correlated to explanation; it means something intelligible enough as a fact, but not accounted for, not reduced to any law, principle, or reason. The ebb and flow of the tides, the motion of the planets, satellites, and comets, were understood as facts at all times; but they were regarded as mysteries until Newton brought them under the laws of motion and of gravity. Earthquakes and volcanoes are still mysterious; their explanation is not yet fully made out. The immediate derivation of muscular power and of animal heat is unknown, which renders these phenomena mysterious.

The meaning of the correlative couple—mystery, explanation — has been rendered precise by the march of physical science since the age of Newton. Mystery is the isolation of a fact from all others. Explanation is the discerning of agreement among facts remotely placed: it is essentially the *generalizing process*, whereby many widely scattered appearances are shown to come under one commanding principle or law. The fall of a stone, the flow of rivers, the retention of the moon in her circuit, are all expressed by the single law of gravity. This generalizing sweep is a real advance in our knowledge, an ascent in the scale of intelligence, a step toward the centralization of the empire of science; and it is the only real meaning of explanation. A difficulty is solved, a mystery is unriddled, according as the mysterious facts can be shown to resemble other facts. Mystery is solitariness, exception, or it may be apparent contradiction; the resolution of the mystery is found in assimilation, identity, fraternity. When all natural operations are assimilated, as far as assimilation can go, as far as likeness holds, there is an end to explanation, and to the necessity for it; there is an end to what the mind can intelligently desire; perfect vision is consummated.

But, say many persons, after resolving the fall of a stone and the sun's attraction into one force called gravity, there still remains the mystery—what is gravity? Even Newton sought to explain gravity itself. Well, if you must go farther, find some other force to *assimilate* with gravity; you will then make a new generalizing stride, and achieve a further step of explanation. If, however, there is no other force to be assimilated, gravity is the final term of explanation, the full revelation of the mystery. There is nothing further to be done, nothing further to be desired. Nor have we here any reason to be dissatisfied with this position, to complain of balked satisfaction, or of being on a lower platform than we might possibly occupy. Our intelligence is fully honored, full implemented, by the possession of a principle as wide in its sweep as the phenomenon itself.

Apply all this to the union of mind and body. These two phenomena have very little in common; they participate only in the most general attributes, namely, quantity, co-existence, and succession, and even as regards these their participation is limited.

As to *quantity*, degree, or distinction of more and less, there is no exemption on the part of either. The properties of every material body are distinguished as more or less; magnitude, weight, color, hardness, etc., have assignable degrees or amounts specific to each substance. So also are the mental properties distinguished as more or less; our pleasures, our pains, our thoughts, may be numbered and measured, although the grades of intensity of the feelings cannot be assigned with the same minute precision that belongs to the leading material properties, such as size, weight, or tenacity. Again, material properties *co-exist;* a plurality may concur in the same object; a diamond has size, form, transparency, and other qualities all co-inhering in the same unity. So mental attributes co-inhere, are attached to a common subject; the same mind feels, wills, and

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hypothesis of separate embodiment.

3. The manner of connection of the nerve-fibres with the cell, and with one another through the cell, is conjectured and figured by Dr. Beale in a plan that facilitates our conception of the physical growths underlying memory and acquisition. (I refer particularly to his paper in the Proceedings of the Royal Society, vol. xiii., p. 386, on the Paths of Nerve-currents in Nerve-cells.) He observed, in certain specimens of the caudate nerve-cells, a series of lines passing across the body of the cell, and continuing into its branches, or communicating with the nerves. He considers these lines as the tracks of nervous action through the cell, being probably somewhat different in substance from the rest of the matter of the cell. He couples with this appearance the doctrine (maintained by him, although disputed by others) that the nerves terminate in loops, and consequently form an unbroken nervous circuit. He then suggests that the cell-crossing is the place where the inner bendings of a great many independent circuits come into close neighborhood, and affect one another by a process of the nature of electrical induction. Any one of the circuits being active, or excited, would impart excitement to all that came near it in the same cell. (See Fig 3 of the paper referred to.)

Now assuming such an arrangement, I can suppose that, at first, each one of the circuits would affect all the others indiscriminately; but that, in consequence of two of them being independently made active at the same moment (which is the fact in acquisition), a strengthened connection or diminished obstruction would arise between these two, by a change wrought in the intervening cell-substance; and that, afterward, the induction from one of these circuits would not be indiscriminate, but select; being comparatively strong toward one, and weaker toward the rest.

thinks. Lastly, material phenomena are in a state of change or mutation; they show successive phases; and in their *succession* we recognize the peculiar and remarkable bond termed causation, or cause and effect. A spark falls into water, it is extinguished; it falls on gunpowder, there is an explosion. The same fluctuation, mutation, succession, and causation, may be traced in the workings of mind; a pain suddenly ceasing is followed by a reaction of pleasure.

The one feature usually signalized as present in all material phenomena, and absent from all states of the conscious mind, is that mode of co-existence called order in place, EXTENSION. A building or a tree is named as an extended thing; a pleasure, a pain, a recollection, is not felt to be extended; there is an incompatibility between a feeling and a perception of extended magnitude. While we are mentally occupied or engrossed with a genial warmth, we are not able to entertain the perception of a room, or a fire, as occupying space.

Bodily facts and mental facts are in themselves equally conceivable, equally intelligible. When we see a table we perceive it in the way suited to our faculties; there is no reservation or mystery attached to it as a table. When we feel a warm surface, we have a sufficient notion of what warmth is. There is a marked difference of nature between these two feelings; they differ much more than a table differs from a house, or the taste of sugar from the sound of an Æolian harp. Yet difference does not interfere with knowledge, but on the contrary adds to it; every new difference is the revelation of a new quality.

I repeat, what a piece of matter is, what an operation of mind is, we know equally well; we see that they both agree and differ from other kinds of matter, and from other operations of mind. There is a much closer kindred between material facts among themselves, and between mental facts among themselves, than between material facts generally and mental facts generally. Hence, we resolve all the facts of nature ultimately into two kinds—matter and mind; and we do not resolve these into anything higher. We come upon a wider contrast at this point than we had in any prior stage of our generalizing movement. The plants and the animals differ widely in their details; both differ still more widely from inanimate matter. Yet they agree in all the principal features of material bodies; and are in total opposition to mind, which has neither the distinctive features of either, nor the common attributes of both. The inanimate and the animate are not so different as body and mind.

Extension is but the first of a long series of properties all present in matter, all absent in mind. INERTIA cannot belong to a pleasure, a pain, an idea, as experienced in the consciousness; it can belong only to the physical accompaniments of mind—the overt acts of volition, and the manifestations of feeling. Inertia is accompanied with GRAVITY, a peculiarly material property. So COLOR is a truly material property; it cannot attach to a feeling, properly so called, a pleasure or a pain. These three properties are the basis of matter; to them are superadded FORM, MOTION, POSITION, and a host of other properties expressed in terms of these—attractions and repulsions, hardness, elasticity, cohesion, crystallization, heat, light, electricity, chemical properties, organized properties (in special kinds of matter).

When we have laid out in full array the properties peculiar to matter, and the properties peculiar to mind, we present two distinct departments of study, having each its difficulties to be overcome. Matter in many of its properties is simple, intelligible, devoid of all mystery, the very type of plainness; such are extension, inertia, gravity. It has other properties less known, but yet not altogether unintelligible, as heat, light, electricity, chemical attraction. A third class are still less understood, and verge on the mysterious, as the vital properties. We do not fully understand how the nutritive processes yield muscular motion; we cannot assimilate the fact with any other known facts, or bring it under any known law.

Mind, in some of its phenomena, is plain enough. We distinguish pleasures and pains, we know many of the laws of their rise, subsidence, and mutual action. We know as a fact that our thoughts follow in trains, and we can resolve many of the successions into general laws of succession; which is, up to a certain point, to explain the phenomena. We are less acquainted with the laws governing the successions in dreaming; these successions are by comparison mysterious to us.

There are thus two knowledges, each advancing on its own way, and gradually extending the region of the plain and intelligible at the expense of the obscure, the isolated, and the unintelligible. So far, there is nothing that any one can complain of, excepting the slowness of our progress. But now we have to take account of a new fact, namely, that these two classes of properties are conjoined in the unity of a sentient being—man or animal. The same being that exhibits the mental powers is a lump of matter, characterized by a great number of the most subtle endowments of matter. A sentient animal has two endowments, two sides or aspects of its being—the one all matter, the other all mind. Notwithstanding the cardinal opposition of the two sets of powers, they are inseparably joined in the same being; they coinhere in the one individual, man or animal. This may seem curious or wonderful, but there is nothing in it to take umbrage at. If mind exists, it must exist somewhere and somehow; for anything we know, it might have existed apart, in a way that we cannot figure to ourselves for want of some example within our reach. In actual fact, it exists in company with a peculiar mass of matter, containing in a very superior degree the properties known as living or organized. Mind is

not associated with mineral or inanimate matter. Does this conjunction interfere with our study of the two separate departments—mind and body—each according to its kind? Apparently not. It cannot interfere with our observation of all those material properties in minerals and vegetables that exist without an alliance with mental powers. It need not interfere with the study even of the highly organized functions of animals, unless these are somehow or other controlled by mental operations, which can be known only by actual examination.

We might thus, to all appearance, proceed in our separate tracts of material and of mental investigation, in spite of the incorporation of the mental with the material in certain living subjects? But now, are we to take any notice of the fact of the *union itself?* Are we to enunciate as a property of matter, that a certain highly complicated material mass can be associated with mind; and as a property of mind, that it is found in alliance with a material body? Surely, if such be the fact, we are at liberty to declare it. May we then call it a mystery? In a certain sense we may. It is a fact isolated and unique, if we look at matter generally; but it is yet of wide prevalence, if we combine the number of individuals of the human race with the still greater numbers of the lower animals. The repetition of it over so wide a field redeems the mystery by familiarity; although it does not take away the bold contrast between the animal nature on the one hand and plants and minerals on the other.

The mystery will be still further reduced if we can resolve the connection as stated in gross, to separate and specific laws of connection. This would be a step of genuine enlightenment in any region of nature. We accept the union as a fact, just as we accept any other union—heat with light, magnetism with the sesquioxide of iron, gravity with inert matter. We then endeavor to express it in its simplest terms, or under the most comprehensive laws. Let us resolve into the highest possible generalities, the connection of pleasures and pains with all the physical stimulants of the senses, with all the suggestions of thought, with all the external manifestations in feature, gesture, movement, and secretion; and when this is done we shall have resolved one part of the mystery by the only mode of resolution that the case admits of. Let us go farther if we can: let us generalize the connections of thought or intellect with nervous and other processes; find out what physical basis specifically belongs to memory, to reason, to imagination, and what are the most general statements of the relationship: we shall then fully, sufficiently, finally explain the alliance of mind and body in the sphere of intellect. There is no other explanation needful, no other competent, no other that would be explanation. Instead of our being unfortunate, as is sometimes said, in not being able to know the essence of either mind or matter, in not rendering an account of their union, our misfortune would be to have to know anything different from what we do or may know. There is surely nothing to complain of in the circumstance that the elements of our experience are, in the last resort, not one but *two*. If there were fifty ultimate experiences, none of them having a single property in common with any other; and if we had only our present limited powers of understanding, we might be entitled to complain of the world's mysteriousness, in the one proper acceptation of mystery, namely, as overpowering our means of intellectual comprehension, as weighing us down with a load of unassimilable facts. But our actual difficulty is far short of this; the institution of two distinct entities is not in itself a crushing dispensation.

It remains to consider the expression most suited to this union of the two distinct and mutually irresolvable natures. By inapplicable phraseology many a question has been darkened and mystified to the point of despair. In the History of Philosophy we find numerous instances of contradictions brought about by inappropriate language; most of all in this very case of mind and body, as will appear in the closing chapter, on the history of the question.

The doctrine of two substances—a material united with an immaterial in a certain vaguely defined relationship—which has prevailed from the time of Thomas Aquinas to the present day, is now in course of being modified, at the instance of modern physiology. The dependence of purely intellectual operations, as memory, upon the material processes, has been reluctantly admitted by the partisans of an immaterial principle; an admission incompatible with the isolation of the intellect in Aristotle and in Aquinas. This more thoroughgoing connection of the mental and the physical has led to a new form of expressing the relationship, which is nearer the truth, without being, in my judgment, quite accurate. It is now often said that *the mind and the body act upon each other;* that neither is allowed, so to speak, to pursue its course alone; there is a constant interference, a mutual influence between the two. This view is liable to the following objections:

In the first place, it assumes that we are entitled to speak of mind apart from body, and to affirm its powers and properties in that separate capacity. But of mind apart from body we have no direct experience, and absolutely no knowledge. The wind may act upon the sea, and the waves may react upon the wind; yet the agents are known in separation, they are seen to exist apart before the shock of collision; but we are not allowed to perceive a mind acting apart from its material companion.

In the second place, we have every reason for believing that there is, in company with all our mental processes, *an unbroken material succession.* From the ingress of a sensation to the outgoing responses in action, the mental succession is not for an instant dissevered from a physical succession. A new

prospect bursts upon the view; there is a mental result of sensation, emotion, thought—terminating in outward displays of speech or gesture. Parallel to this mental series is the physical series of facts, the successive agitation of the physical organs, called the eye, the retina, the optic nerve, optic centres, cerebral hemispheres, outgoing nerves, muscles, etc. While we go the round of the mental circle of sensation, emotion, and thought, there is an unbroken physical circle of effects. It would be incompatible with everything we know of the cerebral action, to suppose that the physical chain ends abruptly in a physical void, occupied by an immaterial substance; which immaterial substance, after working alone, imparts its results to the other edge of the physical break, and determines the active response—two shores of the material with an intervening ocean of the immaterial. There is, in fact, no rupture of nervous continuity. The only tenable supposition is, that mental and physical proceed together, as undivided twins. When, therefore, we speak of a mental cause, a mental agency, we have always a *two-sided cause;* the effect produced is not the effect of mind alone, but of mind in company with body. That mind should have operated on the body, is as much as to say that a two-sided phenomenon, one side being bodily, can influence the body; it is, after all, body acting upon body. When a shock of fear paralyzes digestion, it is not the emotion of fear, in the abstract, or as a pure mental existence, that does the harm; it is the emotion in company with a peculiarly excited condition of the brain and nervous system; and it is this condition of the brain that deranges the stomach. When physical nourishment, or a physical stimulant, acting through the blood, quiets the mental irritation, and restores a cheerful tone, it is not a bodily fact causing a mental fact by a direct line of causation: the nourishment and the stimulus determine the circulation of blood to the brain, give a new direction to the nerve currents; and the mental condition corresponding to this particular mode of cerebral action henceforth manifests itself. The line of mental sequence is thus, not mind causing body, and body causing mind, but mind-body giving birth to mind-body; a much more intelligible position. For this double or conjoint causation we can produce evidence; for the single-handed causation we have no evidence.

The same line of criticism applies to another phrase in common use, namely, "the mind uses the body as its *instrument*," or medium of operating on the external world. This also assumes for mind a separate existence, a power of living apart, an option of working with or without a body. Actuated by the desire of making itself known, and of playing a part in the sphere of matter, the mind uses its bodily ally to gratify this desire; but if it chose to be self-contained, to live satisfied with its own contemplations, like the gods as conceived by Aristotle, it need not enter into co-operation with any physical process, with brain, senses, or muscular organs. I will not reiterate the groundlessness of this supposition. The physical alliance is the very law of our mental being; it is not contrived purely for the purpose of making our mental states known: without it we should not have mental states at all. The imparting our feelings to others, and the setting outward things in motion, are consequences of the alliance, but they are not its primary motive. The resolve on our part to affect other minds is already a physical fact, in company with a mental fact; it is not a whit more physical when carried into overt display.

If all mental facts are at the same time physical facts, some will ask what is the meaning of a proper mental fact? Is there any difference at all between mental agents and physical agents? There is a very broad difference, which may be easily illustrated. When any one is pleased, stimulated, cheered by food, wine, or bracing air, we call the influence physical; it operates on the viscera, and through these upon the nerves, by a chain of sequence purely physical. When one is cheered by good news, by a pleasing spectacle, or by a stroke of success, the influence is mental; sensation, thought, and consciousness are part of the chain; although these cannot be sustained without their physical basis. The proper physical fact is a single, one-sided, objective fact; the mental fact is a two-sided fact—one of its sides being a train of feelings, thoughts, or other subjective elements. We do not fully represent the mental fact, unless we take account of both the sides. The so-called mental influences—cheerful news, a fine poem, and the rest—cannot operate, except on a frame physically prepared to respond to the stimulation.

While admitting that there is something unique, if not remarkable, in the close incorporation of the two extreme and contrasted facts, termed mind and matter, we must grant that the total difference of nature has rendered the union very puzzling to express in language. The history of the question repeatedly exemplifies this difficulty.

What I have in view is this. When I speak of mind as allied with body—with a brain and its nerve-currents—I can scarcely avoid *localizing* the mind, giving it a local habitation. I am thereupon asked to explain what always puzzled the schoolmen, namely, whether the mind is all in every part, or only all in the whole; whether in tapping any point I may come at consciousness, or whether the whole mechanism is wanted for the smallest portion of consciousness. One might perhaps turn the question by the analogy of the telegraph wire, or the electric circuit, and say that a complete circle of action is necessary to any mental manifestation; which is probably true. But this does not meet the case. The fact is, that all the time that we are speaking of nerves and wires, we are not speaking of mind, properly so called, at all; we are putting forward physical facts

that go along with it, but these physical facts are not the mental fact, and they even preclude us from thinking of the mental fact. We are in this fix : mental states and bodily states are utterly contrasted ; they cannot be compared, they have nothing in common except the most general of all attributes—degree, and order in time ; when engaged with one we must be oblivious of all that distinguishes the other. When I am studying a brain and nerve communications, I am engrossed with properties exclusively belonging to the object or material world ; I am unable at that moment (except by very rapid transitions or alternations) to conceive a truly mental fact, my truly mental consciousness. Our mental experience, our feelings and thoughts, have *no extension*, no place, no form or outline, no mechanical division of parts ; and we are incapable of attending to anything mental until we shut off the view of all that. Walking in the country in spring, our mind is occupied with the foliage, the bloom, and the grassy meads—all purely objective things : we are suddenly and strongly arrested by the odor of the May-blossom ; we give way for a moment to the sensation of sweetness ; for that moment the objective regards cease ; we think of nothing extended ; we are in a state where extension has no footing ; there is, to us, place no longer. Such states are of short duration, mere fits, glimpses ; they are constantly shifted and alternated with object states, but while they last and have their full power we are in a different world ; the material world is blotted out, eclipsed, for the instant unthinkable. These subject-moments are studied to advantage in bursts of intense pleasure, or intense pain, in fits of engrossed reflection, especially reflection upon mental facts ; but they are seldom sustained in purity beyond a very short interval ; we are constantly returning to the object side of things—to the world whose basis is extension and place.

This, then, as it appears to me, is the only real difficulty of the physical and mental relationship. There is an *alliance with matter*, with the object, or extended world ; but the thing allied, *the mind proper*, has itself no extension, and cannot be joined in local union. Now, we have a difficulty in providing any form of language, any familiar analogy, suited to this unique conjunction ; in comparison with all ordinary unions, it is a paradox or a contradiction. We understand union in the sense of local connection ; here is a union where local connection is irrelevant, unsuitable, contradictory ; for we cannot think of mind without putting ourselves out of the world of place. When, as in pure feeling—pleasure or pain—we change from the object attitude to the subject attitude, we have undergone a change not to be expressed by place ; the fact is not properly described by the transition from the *external* to the *internal*, for that is still a change in the region of the extended. The only adequate expression is a CHANGE OF STATE : a change from the state of the extended cognition to a state of unextended cognition. By various theologians heaven has been spoken of as not a place, but a *state ;* and this is the only phrase that I can find suitable to describe the vast, though familiar and easy, transition from the material or extended, to the immaterial or unextended side of our being.

When, therefore, we talk of incorporating mind with brain, we must be held as speaking under an important reserve or qualification. Asserting the union in the strongest manner, we must yet deprive it of the almost invincible association of *union in place*. An extended organism is the condition of our passing into a state where there is no extension. A human being is an extended and material mass, attached to which is the power of becoming alive to feeling and thought, the extreme remove from all that is material ; a condition of *trance* wherein, while it lasts, the material drops out of view —so much so, that we have not the power to represent the two extremes as lying side by side, as container and contained, or in any other mode of local conjunction. The condition of our existing thoroughly in the one, is the momentary eclipse or extinction of the other.

The only mode of union that is not contradictory is the union of close succession in *time ;* or of position in a continued thread of conscious life. We are entitled to say that the same being is, by alternate fits, object and subject, under extended and under unextended consciousness ; and that without the extended consciousness the unextended would not arise. Without certain peculiar modes of the extended—what we call a cerebral organization, and so on—we could not have those times of trance, our pleasures, our pains, and our ideas, which at present we undergo fitfully and alternately with our extended consciousness.

CHAPTER VII.

HISTORY OF THE THEORIES OF THE SOUL.

LET me first classify the different views that may be held as to the ultimate component elements of a human being.

I. TWO SUBSTANCES.

1. *Both Material.*

a. The prevailing conception among the lower races.

b. Most of the ancient Greek philosophers.

c. The early Christian Fathers.

2. *An Immaterial and a Material.*

a. Commencement in Plato and in Aristotle.

b. The later Fathers from the age of Augustine.

c. The Schoolmen.

d. Descartes.

e. The prevalent opinion.

II. ONE SUBSTANCE.

1. *Mind and Matter the same.*

a. The cruder forms and expressions of Materialism.

b. The Pantheistic idealism of Fichte.

2. *Contrast of Mind and Matter saved.*

Guarded or qualified Materialism—held by many physiologists and metaphysicians: the growing opinion.

As the present historical sketch is principally occupied with (1) the development, and (2) the decay of Immaterialism, let me further prepare the way by a summary view of the arguments of its supporters, which are also the points of attack of its assailants.

1. The soul must partake of the nature or essence of the Deity.

2. The soul has no determinate place in the body.

3. Reason or thought—the power of cognizing the universal—is incompatible with matter (Aquinas).

4. The dignity of the soul requires an essence superior to matter.

5. Matter is divisible; mind indivisible.

6. Matter is changeable and corruptible; mind is a pure substance.

7. Mind is active, or possesses force; matter is passive, inert, the thing acted on.

8. The soul is the primary source or principle of life.

9. The mind has a personal identity; the particles of the body are continually changing.

The interesting and elaborate inquiries, recently prosecuted with regard to the mental condition and modes of thinking of the lower races have contributed the first chapter of the history of the soul. I allude more particularly to the writings of Sir John Lubbock, Mr. McLennan, and Mr. Tylor, who have thrown a flood of light on the primitive history of mankind; bringing the development of religious ideas up to the point where Greek philosophy took its start.

Mr. Tylor has appropriated the word "Animism" to express the recognition, throughout all the races of mankind, of the soul as a distinct entity. There are two classes of souls: those of individual creatures, like ourselves, capable of continued existence after death, and those of purely spiritual beings of all grades up to the most powerful deities.

As regards our present subject, two distinct problems (says Mr. Tylor) engaged the thoughts of men at a low level of culture. First, What makes the difference between a living body and a dead one—between one awake and one either asleep or in some lifeless condition? Secondly, What are those human shapes appearing in dreams and visions? In early savage philosophy, the two sets of phenomena were made to account for and implement each other, by the conception of an *apparition-soul* or a ghost-soul. The absence of this constitutes the lifeless body; its presence as a visitor made the dream, apparition, or ghost.

The matter, material, or substance of the ghost-soul is a sort of vapor, film, or shadow, impalpable to the touch, and invisible, except on the particular occasions when it manifests itself in dream or vision; exercising physical power; bearing a likeness to the person that it belongs to, and showing itself clad in habiliments and accoutrements; capable not only of leaving the body, but of flashing swiftly from place to place, with a perfect mastery of distance; able to take possession of the bodies of other men, or of animals, and to act through these. As a matter of course, the soul is the principle of life and of all mental activity in the individual that it primarily belongs to. (Tylor, "Primitive Culture," I. 387.)*

The words for expressing the soul show the prevailing conception of its nature or substance. Foremost among these is the "shadow" or "shade," so widely diffused among civilized languages. The "shadow" happily combined two of the requisites of the soul, the *unsubstantial quality*, and the *form* of the individual man; although, if critically considered, it would have various drawbacks. Next comes the "heart," from the connection of the pulses with full vitality: allied to which is the widely-spread identity of soul and "blood." Thirdly, great use has been made of the "breath" in designating the soul; the connection of breathing with life being obvious; *psyche*, *pneuma*, *animus*, *spiritus*, are of this origin; and there are parallels in the Semitic and other languages. The association of life with the "pupil of the eye" has also been traced in various traditions, European and others; from the marked difference between the eye in full health and animation, and its appearance in sickness and in death. (Tylor, pp. 388–391.)†

Thus, we may very fairly say that the sole

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* The possession of a soul was not limited to human beings. That animals also had souls was an equally prevalent belief, and was the foundation of numerous rites and customs. No radical distinction could be drawn between men and animals, as to the possession of the attributes grouped together under the soul.

The analogy between men and plants is much feebler; but it still contains the marked features of life and death, health and sickness. This was enough for endowing plants too with souls. The doctrine of transmigration allows plants to enter into the line of successive tenancy of a spirit. Moreover, the existence of tree-worship carries with it by inference the belief in tree-souls.

The attributing of spirits, or souls, to inanimate objects would seem to proceed upon a very attenuated analogy. In the case of great natural agents, as the winds, the rivers, the oceans, fire, the sun, the circumstance of exercising power is itself a strong point of resemblance, although accompanied with great disparity; the personifying of nature has here its commencement. The so-called object-souls, souls of useful articles—tools, implements, armor, houses, canoes—have a place among the spirits of the inferior races: a purely utilitarian conception of the soul. The often-cited worship of "stocks and stones" is no doubt the lowest degradation of the human faculty of reverence; but the reason of its existence has been assigned with great probability. (Sir John Lubbock, "Origin of Civilization," chap. v.)

† Mr. Tylor traces an interesting result of the plurality of figurative designations for the soul, in the development of a plurality of functions, and even a *plurality of souls;* so early did the ambiguities and confusions of language govern men's conceptions of things.

theory of mind and body existing in the lower stages of culture, is a *double materialism.* This was within their grasp. An immaterial soul was entirely beyond their intellectual comprehension. Until the Greek philosophy taught the world how to use and abuse abstract notions, immaterialism was not an attainable phase of thought.

In turning next, therefore, to the speculations of ancient Greece, we are greatly helped by the well wrought-out delineation of the theories that first constituted the education of the Grecian thinkers. The bold originality and intellectual acumen of the Greeks were displayed in this, as in so many other fields; but they could not entirely free themselves of their inherited bias.

Generally speaking, the Greek philosophers were double materialists. They duly distinguished between the substance of the soul and the substance of the body; but the substance of the soul was still accounted matter —namely, the two higher elements, air and fire; to which Aristotle, subtilizing still further, added an ether, or fifth essence (quintessence). These higher elements made up the celestial bodies, as well as the gods themselves; they were distinguished from the lower couple, earth and water, not merely by their subtle and impalpable consistency, but by the regularity and perfection of their movements; the gross matter below the sphere of the moon was subject to great irregularity, and was on that account an inferior essence. It was not to be expected that the substance of the human soul would transcend the substance of the gods; the assimilation of mind to Deity is common at all stages of culture.

We perceive from this summary view, which will presently be unfolded into details, that the ancient Greeks made a step in advance of the earlier races, by availing themselves of their new physical speculations, whereby they classified the great elements—earth, water, etc.—and distinguished the several characteristics of these. From the "shadow" of the primitive thinker to the air and fire of the Grecian sage there was a great stride in refinement of conception, although there was no essential departure from a materialistic theory.

The ancients differed from the moderns in not admitting the *separate* existence of the soul (although Aquinas understood Plato's pre-existence as separation). Those of them that held the doctrine of personal immortality coupled it with transmigration; the soul in quitting one body found another ready for its reception. After - existence was thus coupled with pre-existence. It was repugnant to these philosophers to suppose an absolute beginning, or creation, either for matter or for mind.

Let us, however, descend to particulars.

The pre-Socratic philosophers made very little way with the nature of the soul. Several of them touched the subject, and brought it under their peculiar scheme of nature in general. Heracleitus adopted the principle of *Mutation* as his basis of explanation of all things; and the soul partook of the common attribute in a higher degree. Its subtlety and fluency enabled it to know all other things. Empedocles is the originator of the doctrine of the *Four Elements*—fire, air, water, earth; with love and hatred as principles of motion, the one uniting and the other disjoining the elements. The soul is compounded in the same way; and on the principle of like being known by like, each of its elements knows the like element in the world. Anaxagoras set up *Nous* or *Mind* as the great prime mover of the world. While all material bodies were mixtures of *all* the simple elements, Nous was the pure, unmixed element; the thinnest and subtlest of all matter, more so than either air or fire, but of great energy: unacted on by matter, it was itself not only cognitive, but active, and the source of all change. Diogenes, of Apollonia, adopted *Air* as the constituent of the soul, at once mobile, all-penetrating and intelligent. Demokritus, the *Atomist,* gave to the element fire, and to the soul, the atoms of spherical figure; it was their nature never to be at rest: they were the sources of all motion.

Pythagoras had called the soul a number and a harmony, like everything else; but some of the Pythagoreans looked upon it as an aggregate of particles of extreme subtlety pervading the air, and in constant agitation.

In these views we see two distinct tendencies: to regard the soul as subtle, *ethereal,* and refined, in contrast with the grossness of solid matter; and to view it as the *active* principle of nature, as self-moved, and the cause of motion in corporeal things.

Plato's theory of the soul was one of the influences determining the modern settlement of the question. It starts from his doctrine of eternal, self-existent ideas or forms, which were anterior to what we call the universe, or the Kosmos. To the formation of the Kosmos, there concurred two factors—the ideas and a co-eternal chaos, or indeterminate matter, in discordant and irregular motion. A Divine Architect, or Demiurgus, on contemplating the ideas, made the world in conformity therewith, so far as the things of sense could be made to correspond with the eternal types. The architect had to contend with a pre-existing power, called necessity, represented by the irregular motions of the primitive chaos; only up to a certain point could he control this necessity, and make it give place to regularity. With such a difficulty to struggle against, the Demiurgus proceeds to construct or fabricate the Kosmos. In its totality this is a vast and comprehensive animated being; the model for it is the idea of animal—the self-animal αὐτόζωον). As created, the Kosmos is a scheme of rotatory spheres, and has both a soul and a body. The soul, rooted at the centre and pervading the whole, is *self-moving,* and the cause of movement in the Kosmical body. The Kosmos, in its peripheral or celestial regions, contains the gods; in its cen-

tral or lower regions of air, water, and earth, are placed men, quadrupeds, birds, and fishes. From the divine part of the Kosmos there was a gradual degeneracy in the creation of men and animals. The human cranium was a little Kosmos, containing a rational and immortal soul, of adulterated materials ; while in the body there are two inferior and mortal souls : the higher of the two situated in the chest, and manifesting energy, courage, anger, etc. ; the lower placed in the abdomen, and displaying appetite. The two lower souls are the disturbers of the higher rational soul, confusing its rotations, and perverting their harmonious properties. Yet notwithstanding its superior dignity, the soul is never detached from the body ; it has the corporeal properties of extension and movement ; and it is the moving power of the whole system.

In comparison with the loftiness and purity of the eternal ideas, the Kosmical soul itself was but an imperfect mixture, or compromise between the ideal and the sensible ; and the human soul could be no better Still, in its participation of the ideas (although conjoined with sense), it was self-moving and immortal.

Aristotle set himself to confute all previous theories of the soul. He rejected the doctrine of self-motion as the property of soul ; he regarded as untenable the favorite theory of perception—"Like is known only by like"—and advanced very pertinent objections to that view. As to self-motion, he considered it incorrect to say that the soul is moved at all ; looking more especially at the intellect or Nous, we might rather say that the state is not movement, but rest or suspension of movement.

Both in his criticism and in his constructive theories, Aristotle made an advance upon his predecessors. His eye for facts and his sobriety of judgment raised him above fanciful and one-sided vagaries. He had studied the actual phenomena of living bodies ; had meditated deeply on the wide chasm that divides the inanimate from the animate world ; animated beings as a whole were to his mind more completely separated from inorganic bodies as a whole, than animals were separated from plants.

But it was the characteristic of this extraordinary genius to work at both ends of the scientific process ; he was alike a devotee to facts and a master of the highest abstractions. In this last capacity he originated many of the subtle distinctions that have ever since permeated human thought.

Whoever would begin at the beginning of Aristotle's philosophy must first master his Four Causes, or conditions of all production : (1) *Matter*, the material cause, what anything is made of—marble, brass, wood, etc. (2) *Form*, the formal cause, the type, plan, or design of the maker—the idea of the statuary, the working plans of the architect ; (3) the *Efficient* cause, or prime mover—human muscle, water, wind, or whatever is the force employed ; (4) the *Final* cause, the end or purpose of the workman—his pleasure, profit, fame.

Having once seen the scope of these four exhaustive conditions of every work of human industry, the reader may let drop the two last, as of far inferior importance, and concentrate his attention upon the distinction between the two first—matter and form, which, more than any of his other distinctions, lies at the root of Aristotle's general thinking. He expands and diversifies the contrast in endless ways. We must observe, however, that matter, as one of the four causes, is not without form, in the literal sense ; a block of marble has its form, although not the form intended ultimately. Now there is some ground for supposing that Aristotle, in pushing the distinction to the logical point of *two abstractions*—an abstract matter and an abstract form, separable, in reasoning, but inseparable in reality—had still clinging to him the original contrast of *rough unshaped* matter, and the *finished production* of the workman. At all events, his account of an individual substance is to regard (1) the form, (2) the matter, (3) the compound of the two.

That he was unduly possessed with the distinction between formed matter and raw material, to the obscuring of the logical distinction, we may infer from his making out a difference of dignity between form and matter. Form is the higher, grander, more perfect entity ; Matter has only a second place. This remark is entirely out of place in the logical distinction between the form of a brass ring, and the matter of it (abstracted from the form).

Matter may be body, but it is not necessarily body. It is intelligible only as the correlate of form. Each variety of matter has its appropriate form, and each variety of form its appropriate matter. There are gradations in matter, from the first matter (materia prima), which has no form at all, to the highest developments which approach near to pure form. The only meaning we can give to these last statements is to suppose that he had in his mind the different stages of elaboration of the material of the globe, from a so-called shapeless mass of mud, to the consummate organization of a living being.

Another distinction struck out and designated by Aristotle, and permanently retained from its corresponding to a difference in the nature of things, was the distinction of *Potential* and *Actual*. Active agents have moments of rest or remission ; they possess power, but do not use it. The eye awake is actually engaged in seeing ; in sleep, it is not deprived of the power, but holds it unemployed. Some form of language was required to discriminate the situation of having power in reserve and quiescence from total want of power ; Great Britain, in time of peace, is not to be confounded with nations destitute of a navy.

The distinction of Potential and Actual serves its own turn in its own way, and has no connection with the other great distinc-

tion. But Aristotle could not help mixing up the two; he sees in matter by itself the Potential, in the imparting of form to matter, the Actual or full reality. There is here apparently a reference to the distinction of the two causes. Matter in the rough is still a compound of matter and form; a block of marble from the quarries is no more devoid of form, in the logical view, than a slab in the frieze of the Parthenon. The transition from the Potential to the Actual as regards bodies, is a transition from one form to another form. Still, for understanding what follows, we must keep in view the identifying of actuality with form in the sense of some superior product of formed material.

We are now to see how he applied these rather shaky distinctions to the great problem of soul and body.

In the antithesis of matter and form—Potential and Actual, the soul ranks not with matter but with form, not with the Potential but with the actual. It has matter (the body) as its correlate; and this matter is highly organized, in other words, fitted with capacities or potentialities, and to these the soul is the complement. The implication of potential matter and actualizing form or soul is the totality of the living being. In his fondness for carrying out distinctions, Aristotle remarks that the living being has its two conditions of dormancy and full exercise, and the first or lowest stage of actuality is quite enough to distinguish it; the second or higher actuality, therefore, need not be introduced into the definition. Accordingly the soul stands thus: "The first actuality (entelechy) of a natural organized body, having life in potentiality."

The strong point of the definition is the closeness of the connection of mind and body. Indeed they are too closely connected; or rather the manner of their connection is incorrectly stated. In point of fact, the two are not relative and correlative, like form and matter (logically viewed). Of correlative couples—as light-dark, up-down, cause-effect, parent-child, ruler-subject, supporting-supported—the one can in no sense subsist without the other; the existence of either by itself is a contradiction in terms; a parent without a child, a thing supporting with nothing to support, are absurd and unmeaning. Now, although, in reality, there is a close alliance between soul and body, there would not be a self-contradiction in supposing them separate; for anything we can see, the body might have its bodily functions without the soul, and the soul might have its psychical functions in some other connection that our present bodies. Indeed, Aristotle himself reserves a certain portion of the soul for independent existence. We must, therefore, pronounce the comparison of soul and body to a correlated couple, as irrelevant and unsuitable.

Nevertheless, out of the alleged mutual implication of the two, Aristotle obtains a very felicitous observation. All the actions and passions of the mind, he says, have two sides—a formal side as regards the soul, and a material side as regards the body. It is the business of two different sets of inquirers to master these two sides. The physical philosopher and the mental philosopher would view the same passions differently. Take, for example, the passion of anger. According to the mental philosopher, anger is the appetite for injuring some one (a truly *mental* fact). According to the physical philosopher, it is a boiling up of blood about the heart, with increase of animal heat (*physical* circumstances). Now, this illustration is perfect as representing the two sets of facts, different and yet inseparable. It was, however, but a casual glimpse, a mere incidental flash in a prevailing gloom. His attempt to carry out the illustration to intellectual states, as memory, merely leads to some correct remarks as to the necessity of a sound condition of the sentient organs and body generally, in order to the exercise of intelligence.

Other modes are given for stating the implication or correlation. The soul is the *cause* and principle of a living body. Of the four causes, the body furnishes the material, and the soul comprises all the three remaining, formal, movent or efficient final.

So much for one phase of the Aristotelian doctrine—the mode of stating the union of the soul with the body. The other phase respects the gradation of souls—a succession of nutrient, sentient, intelligent principles.

The remark has already been made that Aristotle had something like an adequate sense of the difference between inanimate matter and living bodies. As, perhaps, the earliest scientific naturalist, he perceived that the living body was characterized by organization, and by the possession of remarkable powers or functions. He did not so strongly realize the boundary between life without consciousness (as in plants) and life with consciousness (in animals and man). Hence he treated as generically homogeneous all living functions, all the active powers belonging to organized individuals. He applied the higher term "soul" to all the characteristic functions of living bodies, from nutrition up to the loftiest attributes of intellect.

Accordingly, we must start from the *nutritive* soul, the basis of all the others, the first constituent of the living individual, the implication of form with matter in a body organized as a nutritive body; the soul of digestion, nutrition, and propagation of the species. Like all soul (as will be seen) it partakes of the celestial heat, through which animated bodies possess their warmth.

From the nutritive we pass to the higher soul, both nutritive and *sentient*. Herein lies the characteristic superiority of the animal to the plant. There is a great advance in point of dignity, as we may suppose. Applying the universal solvent—form *versus* matter—we are to remark that the soul, as sentient and percipient, receives the *form* of the thing perceived without the matter; which is to beg the whole question of external perception. Nevertheless, Aristotle's dis-

cussion of the senses and sensation at large is full of just and original remarks, and was a real contribution to psychology.

From the sentient soul we pass to the *Noëtic*, the Nous, or intelligence. The drawing of too sharp a line between sense and intelligence has been the fruitful source of confusions in philosophy ; and has lent itself to the doctrine of the immaterial soul. At the same time Aristotle fully recognizes the dependence of intellect upon sensation ; we cannot cogitate or reason without sensible images (phantasms). But to reconcile this with the views that he took of the special grandeur and *isolation* of the Nous was beyond his might. He declares (against his own definition of the soul) that the noëtic function has no bodily organs, that it is form, pure and simple (seeming to contradict further the mutual relationship of form and matter).

At this point, however, he looks out for a new ally. The scene changes from earth to heaven. The human soul is not to be finished without celestial fire.

The grand region of form (pure and unadulterated) is the CELESTIAL BODY, the entire concave of heaven, with its eternal rotations, the abode of all divine natures, comprising the invisible gods; and the sun, moon, and stars. From this celestial region proceeds all life, all force ; to every soul, every form that animates the matter of a living body, it imparts its vital properties. It is needless to comment further on the self-contradictory employment of the abstraction, form, to signify the heavenly substance. Aristotle's physics and astronomy were his weakest parts, and laid him open to the merciless scourge of Galileo. Even there he is not without brilliant inspirations ; but he is led captive, with the vulgar, by the enchantment of distance.

The Nous emanated from a peculiar and select influence of the celestial body ; and its own operations are correspondingly dignified. It cognizes the abstract and the universal. It has two modes or degrees, on which hang great issues. There is, on the one hand, the receptive intellect, *Intellectus Patiens*, and, on the other, the constructive or reproductive intellect, *Intellectus Agens ;* the first perishes with the body ; the second, the *Agens*, is intellectual energy, in the purest manifestation, separable from the animal body, and immortal. The climax is now reached . logical consistency is abandoned ; and there is gained a transcendental starting-point for the immaterialism of after ages. Of the best known Greek sects, the Epicureans denied altogether the survival of the soul. The Stoics affirmed the soul as well as the body to be material, and considered it a detached fragment of the all-pervading soul of the world, into which, after the death of the individual, it was reabsorbed.

Our course takes us next to the Fathers of the Christian Church.

The early Fathers had been pagan philosophers before they were Christians ; they thus brought with them into Christianity more or less of the tenets of their respective philosophical sects. Accordingly, the double materialism of antiquity was a prevailing tenet down to the fifth century. A proper immaterial or spiritual substance, as recognized by us, was as yet incomprehensible to the greater number of men. Such a thing, no doubt, had made a beginning in the Greek schools, but was not as yet fully formed even there ; and it received no aid, either from Judaism or from Christianity. In these early centuries it was very generally held, as essential to the Christian doctrine of future rewards and punishments, that mind should be a corporeal substance ; for only matter could be susceptible to physical pain and pleasure.

In general, we may say, that the early Fathers, whether accepting the Oriental and Greek notions of transmigration and pre-existence, or, like Irenæus and Arnobius, making the immortality of the soul depend upon the will of God in his purposes for the salvation of part of mankind, describe in nearly the same terms the essence of Deity and the essence of the soul. Before and even after the Nicene Council, God was often described as a "sublime light." A converted Epicurean would add to this a human form ; a Platonist would use the term "incorporeal" in the Platonic sense of the word, which was not the modern sense.

From Dr. Donaldson's "History of Christian Doctrine" may be gleaned the views on the soul held by the Fathers of the *second century*, named the APOLOGISTS. They were influenced by Platonic philosophy much less than is generally supposed. The only Platonist among them was Athenagoras. They were much more influenced by the prevailing materialistic tendencies ; Stoicism being what might be called the established religion of the time. Justin Martyr's expressions on the nature of God and the soul are indefinite, but he would not seem to have recognized wholly immaterial spirit : although he rejects the Anthropomorphism of the Jews, he ascribes to God shape and locality ; and though nowhere definite on the state of the soul after death, he considers it heresy to say that the soul is taken up to heaven ; and he holds that men rise with the same bodies. Tatian, however, the pupil of Justin, both is more definite, and recognizes a wholly immaterial spirit conjoined with a material spirit in the human body ; God is immaterial, fleshless, and bodiless. His doctrine is, that there are two spirits in the universe, manifesting themselves in individual varieties of form ; at one time they lived in union, but the lower spirit (the soul) became disobedient, fled from the perfect spirit, and sought a baser fellowship with matter ; yet after all, when reunited as in man with the higher spirit, it becomes immortal. Theophilus does not maintain the immateriality of God ; he only holds with Justin that the form of God cannot be expressed. Athenagoras differed essentially from his contemporaries in regard to the nature of the soul : he does not mention *Pneuma*, or higher spirit ; and he speaks of the soul as purely

spiritual, though with a spirituality liable to be disturbed by its material tendencies.

Clement of Alexandria speaks thus of God: "A positive knowledge of God is impossible: we know only what he is not. He is formless and nameless, though we are right to call him by the noblest names. He is infinite; he is neither Genus, nor Differentia, nor Species, nor Individual, nor Number, nor Accident, nor anything that any positive attribute can be ascribed to." This is certainly not corporeality, neither is it what we mean by an incorporeal nature. It is merely working up a powerful impression, by the rhetorical employment of negatives.

Origen conceived of God as a purely spiritual being—not fire, not light, not ether, but an absolutely incorporeal unity or monad. Only on the supposition of incorporeality can he be considered absolutely unchangeable, for everything material is changeable, divisible, transitory. This is an obvious following out of the transcendental germs in Greek philosophy. "In the world, God, who is himself unextended, is everywhere present by his active power, like the builder in his work, or as our soul, in its sensitive part, is spread through the whole body; only he does not fill evil with his presence." "The human soul, as a created spirit, was inclosed in matter because of sin." With all this Origen further remarks that the word "incorporeal" is not to be found in Scripture, and that a *spirit* strictly means a body.

Tertullian is represented (by Ueberweg) as joining, in the manner of the Stoics, with an ethics tending to the repression of sense, a sensationalist doctrine of cognition, and a materialistic psychology. He is a coarse Realist. "The senses deceive not: all that is real is body. The corporeality of God does not, however, detract from his sublimity, nor that of the soul from its immortality. Everything that is, is body after its kind. The Deity is a very pure luminous air, diffused everywhere. What is not body is nothing. Who shall deny that God is body, though he is a spirit? A spirit is a body of its own kind, in its own form. *The soul has the human form, the same as its body, only it is delicate, clear, and ethereal.* Unless it were corporeal, how could it" (as the Stoics also said) "be affected by the body, be able to suffer or be nourished within the body?" "Man is made in the likeness of God; God, in forming the first man, took for pattern the future man Christ."

The materialism of Tertullian is thus pronounced and decisive. Then, again, Melito wrote a treatise to prove God's corporeality. Gregory Nazianzen conceives of spirit as possessing only the properties of motion and diffusion. Maximus could not accept the immensity of God, because he did not see how two substances could exist together in the same space. Even when the Deity was called incorporeal, this property was not incompatible with visibility under certain circumstances; it meant only a negation, somewhat in the manner of the ancients, of the grosser properties of matter. That spirits could be seen was a very common belief: many persons declared that they had seen the souls of the dying as they left the body. Gradually, however, the attribute of visibility was abstracted from the nature of spirit; and the Deity began to be considered incorporeal, meaning also invisible; but the human soul did not rise at once to the same august distinction. Thus in Origen, the soul would seem to have a middle place between gross matter and the one truly spiritual essence—the Deity. It is to him a matter of astonishment that the *material* soul should have ideas of immaterial things; and he concludes that it must possess, if not an absolute, at least a relative immateriality.

So much for the double materialism prevailing among the early Fathers. We shall next see the beginning of the spiritualistic movement within the Church. At this point, however, we may bring in the Neo-Platonists who represent the closing influence of Pagan philosophy, and acted perceptibly on the later Fathers and the Schoolmen.

Plotinus (204–269 A.D.) agrees with Plato in the grand distinction of the ideal and the sensible, and in attributing to the soul an intermediate nature. He differs from Plato with regard to the relation of the ideas to the One or the Good. While in the Platonic system the One or the Good is included as the highest among the ideas, and all the ideas are considered to have independent existence—in Neo-Platonism it is elevated above the ideas, and is made the source whence they emanate.

The One or the Good is the primary essence, the original unity, from which all things have sprung. It is neither Nous or reason, nor anything cognized by reason; for each of these necessarily implies the other; and the nature of the primary essence, as absolute unity, forbids its being identified with anything implying duality. Things emanate from the One, as rays emanate from the sun. The direct product of the One is the Nous, which is an image of it. The image involuntarily turns toward its original in order to behold it, and, through this act of comprehending what is supra-sensible, it becomes Nous. In the Nous the ideas are immanent, not as mere thoughts, but as its component parts.

The soul is an image and product of the Nous, as the Nous is of the One; and it also in its turn produces the corporeal. It is turned partly to the Nous as its producer, and partly to the corporeal, its product. There is, therefore, in the soul an ideal indivisible element, and a divisible element, from which the material world is produced. The soul is an immaterial substance. It is not a body, nor is it inseparable from a body; for not only the Nous, its highest principle, but even memory, perception, and the vegetative force are separable from the body. The body is in the soul, not the soul in the body. Thus a portion of the soul is without

any body ; and for the functions of this portion the co-operation of the body is entirely unnecessary. Even the faculties of sense are not *contained in* the body ; they are only *present with* it, as forces given by the soul to the various organs for the discharge of their functions. The whole soul is present not only in the whole body, but also in each separate part, not being divided among the members ; it is *entirely present in the whole, and entirely in every part.* In one sense, indeed, the soul is divided, since it is in all parts of the body ; but in each of these parts it is present as a whole.

Here we perceive a distinct advance toward immaterialism. In the Neo-Platonic doctrines are to be found the germs of various ideas that afterward played a prominent part in the present subject. That the lower powers of mind and life are separable from the body, and that the body is contained in the soul, are tenets reproduced in the subsequent development of the subject. The notion that the whole soul is in the whole body and in every part was taken up by Augustine, then by Claudian Mamertus, and from them passed over to the Schoolmen, with whom it was a favorite maxim.

We now proceed to the later Fathers. The spiritualistic movement may be said to be headed by St. Augustine, the most profound and metaphysical of all the Latin Fathers ; by Claudian Mamertus, a priest of Vienne, in the south of France ; and in Asia, by Nemesius, Bishop of Emesa.

But even anterior to Augustine (354–430), there were indications of the coming change. In this view, Gregory of Nyssa (331–394) is of importance. His work on the Creation of Man (says Ueberweg) contains a number of psychological remarks. Scriptural views are mixed up with Platonic and Aristotelian opinions. The possibility of the creation of matter, by the Divine Spirit, depends upon its being the unity of qualities in themselves immaterial. The human spirit interpenetrates the whole body ; it came into existence with the body, and neither before nor after it. *The spirituality of God, which is beyond dispute,* proves the possibility of immaterial existence. The soul is a created, living, thinking, and (so long as it is provided with organs of sense) percipient entity. The thinking power does not belong to matter ; otherwise *matter generally would exhibit it* [a happy hit], and in consequence would assume a variety of artificial forms.

In Augustine's discussion of this subject, the most remarkable point is his clear conception of the contrast between the respective properties of matter and of mind. He maintains that such attributes as length, breadth, depth, hardness, etc., are attributes only of matter, and are unintelligible when applied to mind. "The soul must not be conceived as in any way long, or broad, or strong. These are corporeal properties, and so we are inquiring about the soul after the manner of bodies" (De Quant. Animæ, cap. 3). Thus while other qualities, such as hardness and color, are occasionally mentioned, *extension* is always recognized as the great distinctive attribute of matter.

On this definition of matter Augustine founds his proofs of the soul's immateriality. It does not possess this characteristic property of matter, and therefore it cannot be material. This position he very often states and defends. His principal arguments are drawn from the superiority of the soul to the body, from the nature of consciousness and of memory, and from the equal presence of the soul in every part of the body.

The soul is superior to the body. From it alone are derived life, movement, and sensation, none of which are possessed by the body after the soul has fled. Thus the soul, though working through bodily organs, must be, in its own nature, superior to the body it animates. It is invisible, incorporeal, spiritual.

Several arguments are drawn from our consciousness of mental states. The soul, he says, is known by us directly. Our thoughts, desires, knowledge, ignorance, are better known than the objects around us, since these last are perceived through the medium of bodily organs. If, then, the soul be corporeal, it must be known to us as such. Yet in this direct knowledge of it we have no cognizance of corporeal qualities, such as size, shape, or color ; and hence Augustine concludes that no such qualities belong to it. Moreover, while we positively *know* that thinking and feeling are properties of the soul, we can only *suppose* that it is a material substance. That we have no real knowledge of such a substance is proved by the variety of conjectures about its nature. If we separate what we really *know* from what we only *think*, there remain such properties as life, thought, and feeling, which none have ever doubted.

Another argument is founded on the nature of memory. In the mind are stored up the images of a great variety of material objects. Though the body is small, the mind can take in the images of the widest domains ; "and that it is not diffused through the places is shown by this, that it is not as it were comprehended by the images of the greatest places, but rather comprehends them, not by any inclosing, but by a certain indescribable power" (Contra Epist. Manich., cap. 17). If, then, these images, which resemble bodies, are really incorporeal, we cannot believe otherwise of what has no appearance of corporeal properties. And if the things contained in the mind are immaterial, so also is the mind itself.

Augustine lays considerable stress on the Neo-Platonic subtlety that the whole soul is at the same time in every part of the body. "The soul is at the same time wholly present not only in the entire mass of the body, but also in every particle of it" (De Immort. Animæ, cap. 16). "When there is any pain in the foot, the eye looks, the tongue speaks, the hand moves ; and this would not occur unless what of the soul is in those parts felt

also in the foot; nor if not present in the foot could it feel what has there happened" (Id. ib.). And this presence of the whole soul in every part of the body is not similar to the diffusion of bodies through space; for these are larger or smaller according to the space occupied. Nor is it like the case of a quality, such as whiteness, being wholly present in every part of some concrete object; for the matter that is white in one part has no connection with the whiteness in any other part. Wherefore the soul possesses a peculiar nature of its own, having qualities exhibited by no material substance. In addition to these general arguments, Augustine brings forward special considerations to prove the immateriality of the rational soul. The objects of the reason are incorporeal. The images of corporeal things, which it compares and judges, though resembling matter, are really unextended, and therefore immaterial. Truth and wisdom, which are perceived by the reason, have no trace of material properties. Nor in the faculty itself can we detect any such attributes. It cannot be divided into parts and extended through space in the manner of bodies. From all this, therefore, it is concluded that the rational soul is not material.

In answer to the objection that, if the soul has no length, breadth, or thickness, it must be nothing, Augustine maintains that there are many really existing things that have none of these qualities. Justice, for example, has no extension, and yet it is not merely a real thing, but is of a higher nature than any corporeal object. The Deity is also without these attributes; and whoever believes the soul to be corporeal ought in consistency to hold the same opinion of God. The want of such properties, therefore, really proves the soul to be of higher dignity and value.

Since, then, the soul is not matter, it may be asked by what name we are to call it. Augustine replies that "whatever is not matter and yet has real existence, is properly termed *spirit*" (De Quant. Animæ, cap. 13). This, he says, is supported by the usage of Scripture, though the word is also applied there to the intellectual part alone.

Having drawn so broad a contrast between mind and matter, Augustine felt the standing difficulty of conceiving how the immaterial soul can act on the matter of the body in producing movement. Hence he thought that the soul does not act directly on the denser parts of the body, but on a corporeal substance nearer in its nature to the incorporeal. This substance he calls light and air, and supposes that these are mingled through the denser materials. The commands of the soul are first communicated to this more subtle matter, and by it are immediately conveyed to the heavier elements.

As regards the immortality of the soul, Augustine holds that no created being can be immortal in the same sense as God, since the existence of every creature depends continually on the Divine will. At the same time he maintains that none of the changes we see occurring, either in the soul itself or in the body, tend toward the destruction of the soul. Even matter is not destroyed by change: however the form may be altered, it is still matter as much as before. And if such is the case with corporeal things, we cannot suppose that in this point the soul is inferior to them, since mind of any sort is superior to all material objects. Still further, he reasons that the soul cannot be destroyed by any other created being, whether corporeal or spiritual. Matter, from its inferior nature, cannot destroy it. Nor can any more powerful spiritual being; for one mind is subject to another only in so far as its own will may allow such subjection, and it is evident that no mind will desire its own destruction. Thus the soul can be destroyed by nothing but the will of God.

If it be thought that the soul may die in the sense that, though not destroyed, it may exist without life, Augustine shows that such an idea involves contradiction in terms. The soul is life, and the source of life to everything that lives. "The mind, therefore, cannot die. For if it can be without life, it is not mind, but something made alive by mind" (*non animus, sed animatum aliquid est* —De Immort. Animæ, cap. 9).

The argument from the natural "longing after immortality" is frequently insisted on by Augustine. All men, he says, desire to be happy, and happiness cannot be genuine unless its possessor also desires its continuance. Now no man can be truly happy unless he have what he desires; and so, life must be eternal or happiness cannot be attained. Thus nature demands immortality. If it be objected that this argument implies that all, including even the bad, must attain to happiness, Augustine answers that happiness is granted to the good, not because they desire to live happily, but because they desire to live well. Happiness is the reward of goodness; and since all do not desire a good life, all cannot obtain its reward.

Claudian Mamertus, about the year 470, wrote a treatise "De Statu Animæ," in reply to an anonymous work, afterward known to have been written by Faustus, Bishop of Regium in Gaul. Faustus had maintained that God alone is incorporeal; all created things are matter, the soul being composed of air. Mamertus answers from the Augustinian stand-point. According to Mr. Lewes, he has exhausted all the capital arguments whereby Descartes was thought to have established the doctrine of immaterialism. Omitting his discussion of various points not immediately connected with our subject, and his extensive array of authorities from philosophers, from ecclesiastical writers, and from Scripture, we present in the following sketch an outline of his reasoning:

Man was made in the image of God, and, according to the admission of Faustus himself, the Divine nature is incorporeal. Now, since there can be no resemblance to God in matter, we must believe that this image is to be found in an immaterial soul. Moreover.

the immaterial is of a higher nature than the material; and since the Deity is infinitely good, he will desire to create beings of the highest dignity, without which his works would be incomplete, and, being omnipotent, he will carry out this desire.

Again, the soul is not limited by place (*illocalis*). It is wholly present in every part of the body as well as in the whole, just as God is present through the whole universe; otherwise a portion of it would be lost when any part of the body is cut off. Whereas no material object can be present in more than one place at the same time, the soul at once animates the body, and as a whole sees through the eye, hears through the ear, etc. Its motion is not in space; it takes place only in time; being simply, as he explains, the change of thoughts and feelings. When the body moves, this local motion is not communicated to the soul.

The soul has no quantity, for place and quantity are inseparable. While no being except God is entirely beyond the sphere of the Categories (Aristotelian), it is only matter that is subject to them all; thus the soul has quality, but not quantity. In one sense, indeed, it has measure, number, and weight; but then *measure* must be understood of degrees of wisdom; *number* as the mental perception of external numbers; and *weight* must be applied to the will as the moving power in the mind.

The soul is not contained by the body, says Mamertus, but in reality contains it—as had already been taught by Plotinus. This point he endeavors to prove by Scripture, and then applies it to show that the soul must be immaterial; for no material substance can at once contain the body and be within it as its animating principle. If it be thought a contradiction that the soul is in a place and yet is not bounded by place, Mamertus replies that the universe itself presents a similar difficulty; it cannot be contained in any place, else that place would require another, and so on till we should have to attribute to it the Divine perfection of infinity.

In addition to all these considerations, Mamertus also mentions the argument—previously employed by Augustine, and afterward by Descartes—that reasoning is inherent in the substance of the soul; and as reason is incorporeal, so also is the soul. In a similar manner he also argues from the will and the memory.

In refuting the arguments of Faustus, Mamertus displays force and ingenuity. Thus he fully examines the argument from the corporeal allusions in the parable of Lazarus and Dives. He shows that if these allusions prove the materiality of the soul, they must all be taken in the most literal sense, which cannot be done without producing inconsistencies and absurdities.

Nemesius, Bishop of Emesa, in Phœnicia (who flourished about the year 450), deserves mention as having had an influence in establishing immaterialism in the Eastern Church. He wrote a work on the nature of the soul, in which he occupies chiefly the ground of Neo-Platonism. He holds that the soul is an immaterial substance. It is involved, as Plato had taught, in eternal self-produced motion, from which the motion of the body is derived. He maintains the pre-existence of the soul, and holds that its nature, as suprasensible, involves immortality.

From the fifth century down to the great development of Scholasticism, headed by Thomas Aquinas, in the thirteenth, there occurred no important changes of view in connection with our subject. In this latter period it again emerges into prominence, but now the point of view is changed. All the reasonings of the Schoolmen were cast in the moulds of the Aristotelian philosophy, and cannot be understood until Aristotle's leading modes of thought and expression are first comprehended. (See above under Aristotle, especially the explanations of *Form* and *Matter*, *Actuality* and *Potentiality*.) Thus, although Aquinas was a decided immaterialist, he does not aim, like Augustine and Claudian Mamertus, to show that the soul is without the material attributes of extension, quantity, etc.; he endeavors to prove that it is, in the Aristotelian sense, the actuality of the body and pure immaterial form. Hence in order to trace the development of the views culminating in Aquinas, we must recur to Aristotle.

The course from Aristotle to Aquinas is shown in the following summary from Ueberweg. "Aristotle regarded as form (his highest abstraction and antithesis to matter), immaterial, and yet individual, the Deity, and the active Nous or intellect—the only immortal part of the human soul, leaving uncertain the relation between this immortal Nous and the mortal compound of soul and body. Among his immediate followers, as Dicærchus and Strato, the prevailing view was that all form is immanent in matter. Alexander the Aphodisian ascribes to Deity, but to Deity only, a transcendental existence, free from matter, and yet individual; he makes the human soul depend entirely on matter for its individual existence. The later commentators given over to Neo-Platonism, as Themistius, assert the human Nous to have the same independent and individual existence as the Deity. On this side Thomas Aquinas ranges himself."

Albertus Magnus (1193–1280) deserves to be mentioned in this connection as having influenced the opinions of his pupil Aquinas. He held that the active intellect is a part of the soul, being in each man the principle that confers form and individuality. In this principle are also contained the forces called by Aristotle nutritive and sentient, and hence these latter powers are separable from the body and immortal. Every human soul is immortal by virtue of its community with God.

Thomas Aquinas (1225–1274) represents the highest stage in the development of the Scholastic philosophy. His views on the nature of the soul are to be found in several

of his numerous philosophical and theological works, but they are most conveniently gathered from the first part of his "Summa Theologiæ," where the points are fully and systematically set forth. The following abstract includes only such of his opinions on the soul as concern our present purpose.

In maintaining that the soul is not material, he says it is the primary source of life in all living beings. Now while body may be a secondary source of living operations, as the eye, for example, is the source of vision, body *as such* is not living or a source of life. It must have this power as a body of a particular kind (*per hoc quod est tale corpus*), and the source whence anything receives its character is its actuality. 'The soul, therefore, which is the primary source of life, is not body, but the actuality of body; as heat, which is the source whence bodies are made hot, is not body, but a sort of actuality of body." (Sum. Theol. I. 76, 1.)

The soul of man is an independent substance. For by the intellect man cognizes the natures of *all* kinds of bodies. This could not be, if the intellect were matter, since the thing knowing must have nothing in it of the nature of the objects known; nor, if it cognizes by means of body, because the determinate nature of the medium would hinder it from knowing *all* kinds of bodies, just as a diseased eye distorts vision, or the color of a vessel affects the color of a liquid contained in it. Therefore the intellectual principle works by itself without connection with the body; and as only a substance can thus work by itself, the soul of man is an independent substance. But this does not apply to the souls of brutes; for the sentient soul cannot work of itself, but requires the co-operation of the body.

Thomas holds, as already stated, that the soul is pure form, entirely without matter. As regards the intellect in particular, it could not otherwise cognize the essence of things. Matter is the principle of individuality, and would prevent the intellect from cognizing the universal, just as the sentient powers, which operate through bodily organs, perceive only individual things.

While repudiating the Platonic doctrine of pre-existence, Aquinas maintained the immortality of the soul as flowing from its immateriality. It cannot perish by anything external to itself; for since it is fitting that the beginning and the end of existence should take place in similar ways, what has independent being can perish only of itself. Nor can it perish in this way; for because form is actuality (see above in Aristotle), existence belongs to it from its very nature. "Matter perishes through being separated from its form; but it is impossible that form should be separated from itself; wherefore it is impossible that existing form should cease to have being." (This is similar to the reasoning of Augustine given above, and the latter half of the argument is equivalent to the Platonic view in the *Phædo*, that life is inseparable from the very notion of the soul.)

Besides, says Aquinas, adapting to his own modes of thought the argument from the longing of the soul after immortality, "everything naturally desires existence after its own manner, and in things having the faculty of knowing, desire follows knowledge. Now while sense can know existence only under the limits of space and time (*cognoscit esse sub hic et nunc*), the intellect apprehends it absolutely, and with reference to all time. Hence beings having intellect naturally desire to exist always, and a natural desire cannot exist in vain." (Sum. Theol. I. 75, 6.)

So much for the essential nature of the soul. In a separate discussion, he considers the union of soul and body. Here he inquires whether the intellectual principle is united to the body as its form. He reasons that whatever brings a thing into actuality is its form; and the principle that makes the body living is the soul, from which it receives growth, feeling, motion, and also *understanding.* And unless the intellect thus stands to the body in the intimate relation of form to matter, we cannot comprehend how its actions can be attributed to the man *as his.* The Platonic doctrine, that the soul stands to the body merely in the relation of its moving principle, is repudiated. Thomas adds to all this that the higher any form is, the less it is mingled with matter, and the more does it excel matter in its operations. And as the human soul is the noblest of all forms, some part of its operations has no relation to matter, namely, the operations of the intellect.

Following his master Albertus, Aquinas holds that the nutritive, the sentient, and the intellectual faculties are exercised by one and the same soul. He argues that otherwise a man would not be really one, for the unity of any object comes from the same form that gives it being. Besides, their identity appears from the fact that any operation of the soul, when intensely carried on, hinders any other. Thus the higher form really includes the lower one—the sentient and the nutritive souls of Aristotle. (This opinion received dogmatic sanction at the Council of Vienne, in 1311.)

Aquinas holds the idea, originated by Plotinus, that the whole soul is present in the whole and in every part of the body. But he characteristically distinguishes *three kinds* of totality. The soul is not present in each part as a whole in any quantitative sense, nor is it present in the whole of its powers. This presence as a whole in each part must be understood as a presence of its whole nature and essence.

In discussing the faculties of the soul, Thomas argues that they do not all remain when the soul is separated from the body. Some powers are connected with the soul alone, as intellect and will; and these remain in the incorporeal state. Others are joined to the body, as the sentient and nutritive parts; and these disappear as to actual operation, when their bodily organs perish though they still potentially remain in the soul. The intellect is divided, after Aristo-

tle, into active, theorizing, or reproductive (*intellectus agens*); and passive, or receptive (*intellectus patiens*). An active intellect is necessary in order that the forms of material things, which are mingled with matter, may be made intelligible in actuality. This active intellect belongs to the soul; for though we may suppose (according to the Platonic view) a higher and separate intellect, in which the intellect of man participates—which Aquinas in one sense admits, making the Deity such an intellect—yet we must suppose that this participation gives the human intellect the power of separating the universal from the particular; which is to concede the operation of an active intellect within the soul.

The following diagram exhibits the transition from Aristotle to Aquinas. Let the continuous lines represent the material substance, and the dotted lines the immaterial. Aristotle's scheme stands thus:

A. *Soul of Plants.*
———— Without Consciousness.

B. *Animal Soul.*
———— . . . . . . Body and Mind inseparable.

C. *Human Soul*—Nous—*Intellect.*

I. Passive Intellect.
———— . . . . . . Body and Mind inseparable.

II. Active Intellect—Cognition of the highest principles;
. . . . . . Pure Form; detached from matter; the Celestial substance; immortal.

Compare the position of Aquinas:

A. *Vegetable or Nutritive Soul.*
———— . . . . . . Incorporates an Immaterial part, although unconscions.

B. *Animal Soul.*
———— . . . . . . Has an Immaterial part, with consciousness.

C. *Intellect.*
. . . . . . Purely Immaterial.

Duns Scotus (in the end of the thirteenth century) drew back somewhat from the extreme position of Aquinas. He held that God alone is absolutely pure form; all created beings, including angels and the soul, are composed of form and matter. The matter of the soul, however, is very different from the matter that constitutes bodies; it is a created something, the basis of all finite existence, including corporeal matter itself.

But this protest was without effect. Aquinas had triumphed; the utmost limit of abstraction in the line of dualism had been reached.

Coming down now to modern times, we have to recognize Descartes, as, by pre-eminence, the philosopher of immaterialism (the word spirituality is not used by him). Still, it is not unlikely that John Calvin, who preceded him by a century, had a considerable share in making this the creed of religious orthodoxy.

Calvin substantially adopted the settlement of Aquinas. His views are found in his "Institutes," and in a short treatise "On the Sleep of the Soul," written against the doctrine that the soul is unconscious between death and the resurrection, a view that some of the Reformers were inclined to, in their opposition to purgatory. We follow Calvin's phraseology in the "Institutes." The soul is an immortal essence, the nobler part of man; it is a creation out of nothing, not an emanation; it is essence without motion, not motion without essence. Its power of distinguishing good and evil, the swiftness and wide range of its faculties (so opposed to the brutes), the power of conceiving the invisible God—are evidences that it is incorporeal, being incompatible with body. Then as to the vexed connection with space: the soul is not properly bounded by space; still it occupies the body as a habitation, animating its parts and endowing its organs for their several functions. The strength of Calvin's reasoning is still the "point-of-honor" argument.

Now for Descartes. It is not uncommon to style him the father of modern mental philosophy, so forcibly did he insist on the fundamental and inerasible distinction between matter and mind. Matter' whose essence is extension, is known by the senses, and is so studied by the physical observer; mind, whose essence is thinking, can be known only by self-consciousness, the organ or faculty of the metaphysical observer. He made the distinction (which Reid dwelt so much upon in his "Inquiry") between the mental element and the physical element in sensation; the feeling that we call heat being one thing, the physical property of the fire being a different thing. He stated it as a cardinal principle that nothing conceivable by the power of the imagination could throw any light on the operations of thought; which was merely stating that the feelings and thoughts of the mind were something very different from a tree, a field, a river, or a palace, or anything else in the extended world. He argues for the immateriality of the mental aggregate, or thinking principle.

Descartes was not without his theory of the physical accompaniments of the immaterial principle. He assigned to the soul a definite centre or locality in the brain, namely, the small body near the base called the pineal gland. He explained the mode of action of the brain by the flow of animal spirits along the nerves; but then the effect of these animal spirits was confined to the manifestations of our animal life, and did not connect themselves with the thinking principle or the proper soul. It is well known that he refused mind to animals, treating them as automatons or machines. In the fifth chapter of his "Discourse on Method" he goes very fully into what he considers the impassable distinctions between man and the brutes.

For his clear conception of the difference between matter and mind, Descartes deserves all praise; that was to establish a fact. His appended doctrine of an immaterial sub-

stance is an hypothesis, for which, even if argument would suffice to make it intelligible and tenable, his arguments were singularly inadequate. He gives the often repeated distinction between the divisibility of matter and the indivisibility of mind ; but although this could impose even upon Bishop Butler, it was blown to tatters like a cobweb by the materialists. True, a lump of brass is divisible ; but make it into a watch, and you can no longer split it into two without destroying it as a watch. You can no more cut a man's brain into two working brains than you can bisect his intelligence.

The great rival of Descartes in his own time was Hobbes, with whom substance was body, or matter, and nothing else. Spirit meant only a subtle invisible fluid, or ether (whose existence, however, he took no account of in his philosophy) ; or else it was a ghost, or mere phantom of imagination. But we must go on to the eighteenth-century aspect of the question.

Locke's allusions to the subject are characterized by his usual sagacity and sobriety. He cannot see that we are in any way committed to the immaterial nature of mind, inasmuch as Omnipotence might, for anything we know, as easily annex the power of thinking to matter directly, as to an immaterial substance to be itself annexed to matter. These are his words : " He who will give himself leave to consider freely, and look into the dark and intricate part of each hypothesis, will scarcely find his reason able to determine him fixedly for or against the soul's materiality."

About the close of Locke's career begins the great materialistic campaign of the last century, which may be said to culminate in Priestley. Before Priestley, the most important names on his side (the materialist) were Toland and Collins ; while Samuel Clarke, a leader of the opposition, attacked more especially the materialism of the now forgotten Dodwell. Priestley had to contend with Price, whom he always treated with respect, and with Baxter, an extreme spiritualist, now a shade. Bishop Butler had argued for spiritualism in his " Analogy," but had contributed nothing new to the defence. It will be enough for us to advert to the Priestley stage of the English controversy ; but first let us dispose of De la Mettrie and the continental materialists, who belong to the earlier half of the century.

De la Mettrie is introduced to us by Carlyle, among the boon companions of Frederick, in the early part of his reign. He was a *bon vivant*, a diner-out, and a wit, as well as a philosopher ; and his tragical end has no doubt been often used as a moral against too great fondness for good eating. His books, " Man a Machine" " Man a Plant," are written with much vivacity and cleverness of illustration, and were well suited to make an impression upon the more sceptical of his contemporaries. They are mainly made up of copious illustrations of the influence exercised over the feelings by physical conditions, such, for example, as food, stimulants, etc. " What a vast power there is in a repast ! Joy revives in a disconsolate heart ; it is transfused into the souls of all the guests, who express it by amiable conversation or music." Again : " Raw meat gives fierceness to animals, and would do the same to man. This is so true that the English, who eat their meat underdone, seem to partake of this fierceness more or less, as shown in pride, hatred, contempt of other nations.' So, " Man has been broken and trained by degrees, like other animals. . . . We are what we are by our organization in the first instance, and by instruction in the second. . . . Man is framed of materials, not exceeding in value those of other animals ; nature has made use of one and the same paste —she has only diversified the ferment in working it up. . . . We may call the body an enlightened machine. . . . It is a clock, and the fresh chyle from the food is the spring." He goes slightly into the question whether matter has an inherent activity, adducing examples in the affirmative ; but we shall see this position better argued by Priestley. He will not undertake to decide the existence of a Deity, the arguments for and against are so nearly balanced in his mind, and he is equally uncertain about immortality ; but he thinks materialism the most intelligible doctrine, as contenting itself with one substance, the most comfortable to entertain, and *the most calculated to promote universal benevolence.*

A similar strain of argument, with less wit and more logical concatenation, appears in the " Système de la Nature" of Baron d'Holbach ; but we need not occupy space with him.

Joseph Priestley, besides being a voluminous and able writer on theology, mental philosophy, history, and many other things, was a distinguished experimenter in physical science, as his well-known discoveries attest. He commences his work on " Materialism" by an appeal to what was emphatically the eighteenth-century logic—not the logic of Aristotle, nor even of Bacon, but the logic of Newton ; for Newton was a logician by precept no less than by example ; his four rules of philosophizing were not merely given at the outset of every work on natural philosophy, but were laid to heart and acted out by scientific inquirers. Priestley was also, in consequence of his scientific studies, the fit man to deal with the crude and inaccurate notion, adduced as an argument for spiritualism (8), that matter is a solid, impenetrable, inert substance, and wholly passive and indifferent to rest or motion, except as acted on by some power foreign to itself. In opposition to this view, he shows that matter is essentially gifted with active properties, with powers of attraction and repulsion ; even its impenetrability involves repulsive forces. Indeed, he is disposed to adopt the theory of Boscovich, which makes matter nothing else than an aggregate of centres of force, of points of attraction and repulsion, one toward

the other. The inherent activity of matter being thus vindicated, why should it not be able to sustain the special activity of thought, seeing that sensation and perception have never been found but in an organized system of matter? It being a rigid canon of the Newtonian logic, not to multiply causes without necessity, we should adhere to a single substance until it be shown, which at present it cannot, that the properties of mind are incompatible with the properties of matter. In following out his argument, he presents a well-digested summary of the facts referring to the concomitance of body and mind; and cleverly retorts the doctrine that the body impedes the exercise of our powers, by remarking that, on that theory, our mental powers should be steadily increasing as we approach to dissolution He urges the difficulties of having an immaterial and unextended substance joined with matter in the relation of place, as well as mechanically acting upon matter—points that had never indeed been cleared up to the satisfaction of the immaterialists themselves. As the Fathers had often said, there can be no mutual influence where there is no common property. He is especially indignant at the practice of shielding absurdity under the venerable name of "mystery." He would doubtless have applied Newton's rule against multiplying causes, to forbid the multiplying of mysteries without necessity. And, in general, as to a spiritual substance, the vulgar, like the ancients and the first Fathers, will never be able to see the difference between it and nothing at all. He then takes up the Scripture view of the question, endeavoring to prove that the language of the Old Testament implies only a single substance with spiritual properties or adjuncts; that the same view is most conformable to the New Testament; and that the doctrine of a separate soul embarrasses the whole system of Christianity. Of course he will not admit a middle state, between death and the resurrection; nor that such a state apart from the body has anything to do with the immortality of the soul, which doctrine he rests exclusively on the Scripture testimony to a general resurrection.

Such is a summary of by far the ablest defence of the single-substance doctrine in the last century. It became the creed of great numbers at the end of that century and the beginning of this. The celebrated Robert Hall was for many years a materialist in Priestley's sense; and the occasion of his ceasing to be so can hardly be considered as a refutation of the doctrine. He says of himself, that "he buried his materialism in his father's grave."

Coming down to the present century, we may take Dugald Stewart as a fair representative of the metaphysicians. We find him repudiating materialism; but when we inquire what he understands by it, we see that he really means the confounding of mind and matter under one common phenomenon, or one set of properties—the material properties; as in an unguarded phrase of Hume's, "that little agitation of the brain that we call thought;" for though an agitation of the brain *accompanies* thought, it is not itself the thought.* Stewart says that "although we have the strongest evidence that there is a thinking and sentient principle within us essentially distinct from matter, yet we have no direct evidence of the possibility of this principle exercising its various powers in a separate state from the body. On the contrary, the union of the two, while it subsists, is evidently of the most intimate nature." And he goes on to adduce some of the strong facts that show the dependence of mind on body. He says that the mental philosopher is rightly occupied in ascertaining "the laws that regulate their connection, without attempting to explain in what manner they are united."

The late Professor Ferrier, who in his "Institutes of Metaphysics" has set forth, in a nomenclature of his own, the contrast or antithesis of mind and matter, bestows a somewhat contemptuous handling on the common place spiritualism. We quote his words:

"In vain does the spiritualist found an argument for the existence of a separate immaterial substance on the alleged incompatibility of the intellectual and the physical phenomena to co-inhere in the same substratum. Materiality may very well stand the brunt of that unshotted broadside. This mild artifice can scarcely expect to be treated as a serious observation. Such an hypothesis cannot be meant to be in earnest. Who is to dictate to nature what phenomena, or what qualities inhere in what substances; what effects may result from what causes? Matter is already in the field as an acknowledged entity—this both parties admit. Mind, considered as an independent entity, is not so unmistakably in the field! Therefore, as entities are not to be multiplied without necessity, we are not entitled to postulate a new cause, so long as it is *possible* to account for the phenomena by a cause already in existence; which possibility has never yet been disproved."

Hamilton remarks that we cannot localize the mind, without clothing it with the attributes of extension and place; and to make the seat or locality a point only aggravates the difficulty. We have no right to limit it to any part of the organism; the mind cannot

* It is not often that either single-substance materialism or double materialism is exemplified by moderns, except through incaution in the use of language. Robert Hooke (quoted by Dr. Reid, "Intellectual Powers," Essay II., chap. ix.) indulges in a materialistic strain, not unlike some of the ancient philosophers. "In his lectures upon Light he makes ideas to be material substances; and thinks that the brain is furnished with a proper kind of matter, for fabricating the ideas of each sense. The ideas of sight, he thinks, are formed of a kind of matter resembling the Bononian stone, or some kind of phosphorous."

A materialism of this kind pervades Darwin's *Zoonomia*, from which the following expressions are quoted by Mill ("Logic," Fallacies, chap. iii. § 8): The word *idea* "is defined a contraction, a motion, or configuration, of the fibres which constitute the immediate organ of sense;" "our *ideas* are animal motions of the organ of sense."

be denied to feel at the finger points. The sum of our knowledge of the connection of mind and body is, that the mental modifications are dependent on certain corporeal conditions; but of the nature of these conditions we know nothing. (Lectures on Metaphysics, ii., 127.)

The reply may be given to Hamilton that, in one signification of the words, it is correct to say that we know nothing of the corporeal conditions of mind, namely, that they are generically distinct from mind itself; that they cannot be resolved into mind, and mind cannot be resolved into them. In another signification, however, we know a great deal respecting these material conditions and may one day know all that is to be known about them. Indeed, something has been known from the very beginning of human observation.

It is quite true, as Hamilton remarks, that to localize mind is to run into contradiction and absurdity. This, however, may be averted by adapting our phraseology to the peculiar nature of the things; in speaking of mind, we must avoid the language of extension or place.

Mansel ("Prolegomena Logica," p. 138) remarks: "To this day we are ignorant how matter and mind operate on each other. We know not how the material refractions of the eye are connected with the mental sensation of seeing, nor how the determination of the will operates in bringing about the motion of the muscles." Here there is the erroneous assumption that power or efficiency belongs to mind in the abstract. Assume the alliance of mind and matter, and there is nothing hopeless in seeking an explanation of their mutual action. The alliance itself is an unaccountable, because an ultimate, fact; of it no explanation is competent or relevant, except generalizing it to the uttermost.

Again, says Mansel, "We can investigate severally the phenomena of matter and mind, as we can severally the constitution of the earth, and the architecture of the heavens; we seek the boundary line of their junction, as the child chases the horizon, only to discover that it flies as we pursue it." The mistake is in looking for a boundary line at all. We look for a boundary between two parishes, two estates, two adjoining tissues of the animal framework; but between the extended body and the unextended mind the search for a boundary line is incompetent and unmeaning.

I now pass to the latest phase of this eventful history.

A movement in favor of materialism has arisen in Germany within the last twenty years; which is in part a reaction from the high-flown philosophy that so long prevailed, and in part an application to mind of the physical science of this century, as Priestley in his day applied the physical science of the last century.

It is to be remarked, however, that spiritualism, in the form of dualism, was never the philosophic creed of Germany. Kant, who ridiculed alike materialism and idealism, yet did not ascribe to matter a real existence by the side of an independent spiritual principle. Fichte and Hegel, being overmastered with the idea of unity, had to make a choice; and attaching themselves by preference to the dignified mental side, became pantheists of an ideal school, resolving all existence into mind or ideas. People generally, when tired of Kant's critical position, became either materialists or idealists, and not believers in two substances.

As regards the recent materialistic movement, scientific men first broke ground. Emphatic utterances were made by such men as Müller, Wagner, Liebig, and Du Bois Raymond, all tending to rehabilitate the powers of matter. But the outspoken and thorough-going materialism begins with Moleschott, who in 1852 published his "Circular Course of Life," a series of letters addressed to Liebig. In 1854 Vogt came into the field, in an attack upon Wagner, the great physiologist, who had said that, although nothing in physiology suggested a distinct soul, yet this tenet was demanded by man's moral relations. In a series of subsequent works, Vogt has urged the dependence of mind on body, in extreme and unnecessarily offensive language. The third and most popular expounder of these views is Büchner, in his book "Matter and Force," which was first published in 1856, has run through a great many editions, and has been also translated into English.

It is not necessary to expatiate upon the views of these writers. Their handling turns partly on the accumulated proofs, physiological and other, of the dependence of mind on body, and partly upon the more recent doctrines as to matter and force, summed up in the grand generality known as the correlation, conservation, or persistence of force. This principle enables them to surpass Priestley in the cogency of their arguments for the essential and inherent activity of matter; all known force being in fact embodied in matter. Their favorite text is "no matter without force, and no force without matter." The notion of a quiescent impassive block, called matter, coming under the influence of forces *ab extra*, or superimposed, is, they hold, less tenable now than ever. Are not the motions of the planets maintained by the inherent power of matter? And, besides the two great properties called inertia and gravity, every portion of matter has a certain temperature, consisting, it is believed, of intestine motions of the atoms, and able to exert force upon any adjoining matter that happens to be of a lower temperature. Then they ask with Priestley and Ferrier, "Why introduce a new entity, or rather a nonentity, until we see what these multifarious activities of matter are able to accomplish?" They also reply to the spiritualistic argument based on the personal identity of the mind and the constant flux of the body, by the obvious remark, that the body has its

identity too, in *type* or form, although the constituent molecules may change and be replaced.

It is not to be supposed that these writers are in the ascendant in Germany, or that their language is always metaphysically guarded. Still, having written intelligible books, easily appealing to a palpable and determinate class of facts, they have been extensively read; and their ideas, or the scientific facts that they are based on, are modifying even the highest transcendentalism of that remarkable country.

The rapid sketch thus given seems to tell its own tale as to the future. The arguments for the two substances have, we believe, now entirely lost their validity; they are no longer compatible with ascertained science and clear thinking. The one substance, with two sets of properties, two sides, the physical and the mental—a *double-faced unity*—would appear to comply with all the exigencies of the case. We are to deal with this, as in the language of the Athanasian Creed, not confounding the persons nor dividing the substance. The mind is destined to be a double study—to conjoin the mental philosopher with the physical philosopher; and the momentary glimpse of Aristotle is at last converted into a clear and steady vision.

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